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Report

OF THE

Ontario Iron Ore Committee

WITH APPENDIX

1923

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Report of the Ontario Iron Ore Committee with appendix 1923

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PROVINCE OF ONTARIO
DEPARTMENT OF MINES

Hon. Charles McCrea, *Minister of Mines* Thos. W. Gibson, *Deputy Minister*

Report

OF THE

Ontario Iron Ore Committee

WITH APPENDIX

1923

PRINTED BY ORDER OF
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To the Honourable Harry Mills,
Minister of Mines.

Sir,—The committee appointed by Order in Council, October 25th, 1922, to make research, investigate, and report upon the extent and quality of the deposits of low-grade iron ores in Ontario, the best commercial methods of beneficiating the same, and, generally, what steps or measures should be adopted to enable the low-grade and other iron ores of this province to be utilized in the production of pig iron and steel, has the honour to submit its report herewith.

A summary of the report is first presented under the heading, "Conclusions and Recommendations," and a more detailed discussion of the same subjects, as well as statistical data and special articles, follow in twelve chapters and an appendix, listed as follows:—

The appendix to the report contains such information bearing on the subject generally as may prove interesting and useful to those desiring a more detailed knowledge of the iron ore mining industry. Much confidential information was supplied to this committee that proved very helpful in formulating its final conclusions and recommendations.

We have the honour to submit herewith our report for your consideration.

ONTARIO IRON ORE COMMITTEE,

(Signed) LLOYD HARRIS, *Chairman*
" J. G. MORROW
" GEO. A. GUESS
" H. E. T. HAULTAIN
" GEO. S. COWIE
" R. J. HUNT

Toronto, April 28th, 1923.

ACKNOWLEDGMENTS

During the course of the investigation carried on by this committee, much needed assistance and information was readily and cheerfully extended, and our grateful acknowledgment is hereby tendered to the following persons:—

Prof. W. R. Appleby, Dean of the College of Mines, University of Minnesota, Minneapolis, Minn.
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M. Francis, President, Chamber of Commerce, Port Arthur, Ont.
W. Webster, Secretary, Board of Trade, Fort William, Ont.
Chas. Hayden, Chairman, Board of Directors, The International Nickel Co., 25 Broad Street, New York, N.Y.
Wm. Camp, Pittsburg, Pa.

REPORT OF THE ONTARIO IRON ORE COMMITTEE, 1923

CONCLUSIONS AND RECOMMENDATIONS

Introduction

By an Order in Council, dated October 25th, 1922, the text of which is given in Chapter II, this committee was appointed, "to make research, investigate, and report, upon the extent and quality of the deposits of low-grade iron ores in Ontario, the best commercial methods of beneficiating the same, and, generally, what steps or measures should be adopted to enable the low-grade and other iron ores of this province to be utilized in the production of pig iron and steel."

Four members of the committee had been previously engaged in gathering data on the same problem, under the direction of the Honorary Advisory Council for Scientific and Industrial Research, and all members recognized the work and responsibility involved in accepting the task. Against this diffidence was balanced an appreciation of the importance of finding some method whereby our iron ores might be utilized and the iron and steel industry of the province made less dependent upon foreign ores.

Early in November, 1922, the Government intimated their desire that this report should be presented during the present session of the Provincial Legislature, and it was immediately apparent that there was no time for research and that in our estimate of the extent and quality of the iron ore deposits in Ontario, we would be entirely dependent upon examinations already made, and such infromation as we could obtain from those who had reported.

Immediately following the organization of the committee, different members were made responsible for the information required on each phase of the inquiry. So far as time permitted, the literature on the subject was consulted and, later, trips were made to different iron mining districts and to most of the beneficiating plants where ore or beneficiating problems were in any respect similar to our own.

In this work of investigating methods, in gathering statistical information, and in obtaining opinions from those well qualified from experience to advise, we met with unfailing courtesy and co-operation. Our grateful acknowledgment is herewith expressed and is more specifically recorded in another section of this report.

Having gathered, summarized, and digested the available information in connection with this inquiry, the committee is of the opinion that practically speaking each iron ore deposit constitutes a problem in itself. Each differs from the others in its geographical location with respect to markets. Differences in physical structure and chemical composition prevent any one particular plan being generally adaptable to their treatment.

In a general way, under certain conditions set out under Recommendations, we believe:—

(1) That the magnetic iron ore deposits running 50 per cent. in iron and upwards, though high in sulphur, can be commercially sintered and otherwise treated to obtain a suitable product for the blast furnace.

(2) That some deposits of banded and other low-grade magnetites favourably situated with respect to markets, do lend themselves to commercial exploitation.

(3) That some siderite ores can be commercially sintered to obtain a first-class product.

(4) That the application of magnetic concentration methods for low-grade magnetites and subsequent sintering is an art that during the next few years will show remarkable progress, the beginnings of which are already in evidence. A high-class, much-desired product can be obtained. Positive evidence of the feasibility of treatment will probably be available within the year.

(5) That a market can be found in Ontario, annually, for approximately 750,000 tons of sintered ore.

(6) That the pig iron capacity of Ontario furnaces is sufficient to supply all the requirements of the province.

(7) That before any of the special processes for the production of iron and steel can be made applicable to our own deposits, the ore must be concentrated or otherwise beneficiated, and that the product of such treatment can then be more economically treated in the blast furnace than by any other known process.

Ontario Iron Deposits

By reference to the list of known iron ore deposits and their description, as included in the Appendix to this report, it will be seen that, with the exception of the Helen Mine hematite deposit, now worked out, there have been to date no discoveries of iron ore in this province that in their natural state can be classified as commercial ore bodies. It must not, however, be assumed that our chances of finding such ore are by any means eliminated.

In fact, when we consider that even the larger and more important iron ranges in the United States had few surface outcrops to guide the prospector and that their present known dimensions have been ascertained only after many years' continuous development and the expenditure of huge sums of money, and when we realize the comparatively small amount of work done in Ontario, it is apparent that we have but touched the margin of our probable iron ore resources.

It is with some satisfaction that we assert that, although to-day Ontario iron ore requirements are supplied wholly from the United States, we could, if stern necessity demanded, produce from our own deposits sufficient ore to maintain our own furnaces in blast.

Our Present Source of Supply

In Chapter III, this subject is discussed at length, and the assertion is made that the cost of transportation limits our present source of supply to the Lake Superior iron ore deposits. It is apparent to those who study the situation that although there may be enough ore in the United States Lake Superior iron ranges to maintain production at the present rate for at least thirty and perhaps fifty years, yet it is so owned and controlled by those who require it

for their own furnaces that a very limited tonnage of free ore, or ore available to Ontario on the open market, remains. It is not possible to state exactly how long we can continue to procure our requirements, in the present day manner, for reasons stated in the chapter above referred to. Nevertheless, one particularly well-informed Ontario operator, whose experience extends from the beginning of steel manufacture in this province, expressed to the committee the considered opinion that to-day there is not half as much free ore available to Ontario furnaces as there was five years ago.

The unanimous opinion of this committee is that our iron and steel industry will suffer severely as the United States Lake Superior ore reserves, now being rapidly used, are conserved to a greater and greater extent for American furnaces; and that we must, during the next ten years, build up an iron mining industry that will largely free Ontario from the necessity of importing ore.

The iron and steel industry is essentially basic in the development and commercial enterprise of any country. We have succeeded in establishing a steel industry that is a credit to Ontario, that is exerting and must continue to exert a very important influence upon our future expansion, and that during the last two years of the war stood between us and failure in the manufacture of munitions. Proud as we are of this record, we must record the fact that in Ontario, and for that matter in all Canada, no iron ore is being produced and that this all important industry, so far as this province is concerned, is based wholly upon a rapidly dwindling foreign supply that is within measurable distance of extinction.

The problem of providing a domestic supply of iron ore for our furnaces is a very real one and presses for an immediate solution.

Prospecting for Iron Ore

The phenomenal growth and success of precious metal mining in Ontario has attracted to that branch of the industry most of the experienced prospectors. Who could expect these wonderful, daring pioneers to forsake their pursuit of the great prize that is continuously before their mind's eye, with all its promise and colour of romance, for the prosaic task of finding iron ore. Prospecting for iron ore, assisted as far as possible by the work of the provincial geologists, must largely depend upon those who require the material for their own purpose. Well-planned, well-organized effort, along scientific lines, is required. An increased knowledge of structural geology, coupled with the information that can properly be obtained from magnetic surveys and diamond drilling, must generally precede success in this effort. We believe that in our immense pre-Cambrian area, there will yet be developed iron ores which in their natural state will provide suitable material to support and maintain our own furnaces.

Beneficiation

Beneficiation is a term essentially intended to cover all methods whereby iron ore, in any way unsuitable for direct use in the blast furnace, may be made amenable to present day practice. This definition is intended to cover ordinary concentration, whereby waste rock is eliminated and the relative proportion of iron increased, as well as roasting, sintering, and other processes where an undesirable constituent is wholly or partially eliminated, or where the physical characteristics are changed to meet furnace requirements.

The art of preparing iron ore for the blast furnace covers a wide range of activity. The world's insistent and constantly increasing demand for iron and steel products is rapidly exhausting the merchantable iron ore bodies situated near the great centres of distribution for iron and steel products. The enormous increase in the cost of transportation is turning the attention of furnace men to hitherto neglected and comparatively low-grade deposits. As to whether or not any particular iron ore deposit can be beneficiated to-day, at a cost that will permit its economic utilization, is engaging the best effort of many metallurgists. With increased and vastly improved mechanical practice and equipment, problems that were outside reasonable consideration a few years ago are now quite possible of solution. Perhaps the greatest progress has been made in sintering, a process having the combined function of roasting and agglomerating. By passing a raw magnetic or siderite ore through this process, the sulphur can be largely eliminated and a product obtained that by reason of its size, hardness, and porosity is particularly well fitted for the blast furnace. Of special importance is the fact that a comparatively small amount of fuel is required in the sintering process.

In the early days of the iron and steel industry of the United States, the only ores available were the magnetites of the New England area. Some of these ores contained high sulphur and much titanium, but with comparatively crude equipment the operators continued to make progress until the discovery and development of the higher grade, more easily produced ores of the Lake Superior district. Later, with keener competition and the abnormal rise in freight rates, the eastern furnace operators were forced to turn again to local deposits to meet their requirements. Here was the field for the present day sintering process. So successful has this effort been that the use of Lake ores has been largely eliminated, and furnaces are being burdened, in some places, with an all raw magnetite charge and, in others, with varying proportions of magnetic sinter. In the case of one particular furnace the charge is one hundred per cent. sintered magnetite.

A large scale plant for beneficiation of magnetite is in operation at Babbitt, Minn., and in Ontario efforts to utilize low-grade ore have been been made at Port Arthur, Trenton, Moose Mountain, and Magpie. Each of these plants is described in succeeding chapters of the report, and some of them will again be referred to in this chapter in discussing costs of production.

Special Merits of Sintered Ore

In using a sintered ore, the rate of driving can be materially increased because of the open nature of the sinter. This porous structure exposes a large surface to the action of the blast furnace gases, and reduction takes place more rapidly than with natural ores. This increases production to a considerable extent.

Flue dust losses on a furnace operating on sintered ore are very low. It is, therefore, possible to blow more air than with fine hematites, without driving the furnace too fast for proper reduction.

One of the greatest advantages is the exceedingly smooth, regular, and easy operation of the furnace on this material. The burden settles evenly over the entire section of the furnace stock column, eliminating almost entirely

hanging and slipping, and effecting a considerable saving. A high blast heat can be carried, which, when coupled with increased blast, effects a saving in fuel.

The amount of capital invested in a blast furnace and its complementary equipment is enormous. Interest on investment is a big item in the final cost statement.

The number of men necessary to operate a blast furnace does not vary with the tons of pig iron produced. On the other hand, if the furnace output can be increased, say 10 per cent., by using more easily fluxed and higher grade ores, there will be a corresponding decrease in labour and interest charges.

The same argument holds good with respect to cost of transportation. The freight tariff on iron ore makes no distinction between low and high grade ores. If the total charges for transporting a ton of ore from mine to furnace are $3.20, it is apparent that the cost per unit of iron, in a 50 per cent. ore, is 6.4 cents, as against a unit cost of 5 cents in the case of 64 per cent. ore.

Summing up, then, we see that while high-grade, beneficiated iron ores are more difficult and costly to produce, they are more easily and cheaply treated in the blast furnace. Just how far decreased cost of treating these ores in the furnace balances the added cost of producing them, is unknown to this committee and perhaps will not be capable of definite computation for some years. Furnace men in the market for ore will naturally be slow to admit the full value of these beneficiated ores and, indeed, they may not experience their full value until their furnace design is somewhat changed.

Special Processes

In view of our lack of coal and our numerous undeveloped water powers, the suggestion seems natural that we should attempt to smelt our low-grade iron ores by the electric furnace, or some other such method. The great difficulty is that each of these processes requires that the ore be first concentrated, or beneficiated, and for treatment after such preliminary work, no process known to this committee can compete commercially with the blast furnace.

Of course, by certain special methods a very pure iron can be produced. For certain purposes this particular product commands a high price and can be produced at a profit, but the market available is a very limited one. If the production of such high quality iron were largely increased, it would have to compete in the open market with the blast furnace product, which, though not so pure, is produced at a much lower cost and is for most purposes equally serviceable under ordinary conditions.

Generally then, any production by present known electric furnace methods, or by other processes, has too narrow a market to be considered as more than a side issue in the main problem under consideration.

We must continue, for the present at least, to depend upon the modern blast furnace.

Costs at United States Mines

The cost of producing iron ore is governed by so many factors that, practically speaking, each mine is a law unto itself. Each ore deposit presents its own particular problem for consideration in deciding upon the proper method of mining. Some deposits can be mined from the surface; others must be mined from depth. Some ore bodies are uniform in quality and can be mined as a

whole; others are erratic and must be selectively mined, and the different bodies perhaps blended to make a certain grade. Some mines are dry; others are wet and entail heavy pumping charges. Some are situated near the furnace; others are at greater distances, and transportation charges vary, of course, with the geographical situation of the mine. Specific costs under certain conditions are a matter for study on the part of the individual operator.

The average cost over the whole United States Lake Superior iron ore region is, on the other hand, very important, since it gives us some indication of the conditions of competition that must be faced by an Ontario producer.

Generally speaking, the profit on iron ore production in the United States is small, and can perhaps be fairly estimated as averaging not over 80 cents per ton. About 26 per cent. of the total cost is transportation by rail and water to Lake Erie ports. Royalty paid amounts to about 61 cents per ton shipped.

As explained in Chapter III, the amount of taxes paid by the iron ore producers in the United States does not vary with the amount shipped, or the price obtained. The taxes paid per ton shipped varies with changes in the amount of ore produced from year to year. In a year of great activity they are comparatively low on a per ton shipped basis. In a quiet year the condition is exactly the opposite.

However, as will later be explained, this is a very important item, and the following statement will impress that importance upon the reader:—

COMPARATIVE STATEMENT OF DIRECT TAX COSTS ON THREE PARTICULAR IRON ORE PROPERTIES OPERATING IN THE LAKE SUPERIOR DISTRICT, U.S., 1912-1922

	1912	5 year average 1912-1922 incl.	1922
Tax rate per $100[1]	1.58	1.878	6.16
Tax cost per ton produced	.0784	.0876	.4135[2]

[1] See Chapter III.
[2] Compares with average mine labour cost of $0.594 per ton for producing ore.

Here it will be noted that taxes per ton of iron ore produced amount almost to the cost of labour employed in that operation. The 1922 tax rate as shown has risen to 328 per cent. of the average for the ten years preceding, and the tax cost per ton of ore on the same comparison, has risen to 472 per cent.

Cost of Producing Iron Ore in Ontario

So far as we know at the present time, Ontario has no large deposit of iron ore that can be marketed before being beneficiated. In considering costs then, we must include the cost of beneficiation required for any particular ore.

Moreover, we have knowledge of no soft ore, open pit, steam shovel propositions, and our cost for actual mining will be somewhat higher than the average cost in the United States Lake Superior district. Then again, in handling ore that must be so treated, one must not overlook the fact that one ton of raw ore does not make one ton of finished product. In the case of magnetites, the ratio of concentration is around 2.4 to 1, and in the siderites, it is about 10 to 7.

Considering the siderites, where the ratio is least, we see that to produce 7 tons of product acceptable to the blast furnace, the mine must produce 10 tons, and the beneficiation plant must treat 10 tons of raw ore, and this naturally adds to the cost. The higher concentration ratio in treating fine disseminated magnetites that must be magnetically concentrated before sintering, is somewhat offset by the high iron content in the finished product. In the case of Eastern and Western Ontario magnetites that require no concentration before sintering, the ratio is lower even than that applicable to siderites.

Since in the history of beneficiating iron ores in Ontario the Algoma Steel Company's effort at Magpie more nearly approached commercial success, and because their experience is based upon the production of more than 1,000,000 tons of finished product, we can best centre our investigation of comparative costs on this class of ore.

The estimated difference between average U.S. operating mining cost for natural ores and Algoma cost of mining 1.3 tons of raw ore at the Magpie mine to produce 1 ton of finished product, was 89 cents in favour of the U.S. mines. At the Helen mine where there are 12,000,000 to 15,000,000 tons of raw ore above the adit level and an ore body presenting many working advantages over the shaft mine at Magpie, it has been carefully estimated that this relative difference would be reduced to		$0.66
Add estimated cost of sintering by Dwight & Lloyd or Greenawalt process, per ton of sintered product		1.25
Excess cost of producing New Helen sinter		$1.91
Deduct compensating advantages to Ontario producers:		
Average royalty paid on the U.S. side	$0.61	
Average taxes paid on ore for Ontario from the U.S.	.41	
		$1.02
Net advantage to U.S. mines per ton of product		$0.89

The average profit made by the United States iron producers in the Lake Superior district is approximately 80 cents per ton. If we deduct this amount from the 89 cents shown, it is apparent that our estimate shows a loss of 9 cents per ton of sinter produced at the New Helen mine.

The Algoma Steel Company's sinter from the New Helen deposit will grade Old Range Bessemer and non-Bessemer, which means that it would command a price on the open market slightly better than the average. In the early stages of development the cost of production will slightly exceed the market price of their product, but as the mine is developed and markets expand, thus permitting increased production, costs can be gradually decreased until within a few years they should be permanently established on a commercial basis.

Some of the Eastern and Western Ontario magnetites, high in sulphur, but also high in iron and requiring only crushing and sintering to make them suitable for the blast furnace, may be produced at slightly lower cost, but the expense incurred in marketing may largely, if not wholly, balance this advantage.

Magnetites which are low in sulphur but which require fine grinding before concentration, are more expensive to prepare for the furnace; but this disadvantage is partially balanced by the high quality of the sinter produced. The work that is being done at the Babbitt plant of the Mesabi Iron Company will demonstrate the actual cost of beneficiating this type of magnetic ore; but here in Ontario, as previously stated, final calculations must be based upon individual conditions.

This committee believes, then, that some of the higher grade magnetites (over 50 per cent. iron natural) and siderites, such as are found at the New Helen mine, can be produced to-day at a cost approximately equal to their market value, but there is little in the present iron ore mining situation in Ontario that would attract capital. Some new factor must be introduced if we are to get the industry under way in the near future.

Is an Iron Ore Industry in Ontario Worth Fostering?

The basic necessity of a well proportioned iron and steel industry in any country is universally recognized in the realms of commerce. Ontario has a steel industry of which she is properly proud, but most thoughtful people accept with real apprehension the statement that this steel industry is entirely dependent for its raw material upon a foreign country. Everyone in Ontario must wish that conditions were different and hope that something can be done to provide our necessities from our own resources.

But aside from the purely patriotic standpoint, there are many good reasons why iron ore mining should be fostered in Ontario, reasons that must appeal to the Dominion as well as our Provincial Government.

Traversing the north central part of Ontario are our iron ranges, extending mostly through sparsely settled, undeveloped districts. Through these same areas, which to-day offer little in the way of originating freight traffic, our railway systems have extended their transcontinental and branch lines. Because they are the real links between Western and Eastern Canada, these lines must be maintained and improved at the same cost as other higher earning portions of the system. When railway deficits on our National line are under discussion, the remedy suggested is more settlers and more traffic.

Now it is estimated that the iron ore mining and steel-making industry account for well over 20 per cent. of all freight revenue earned by Class I United States railways. No other single industry can compete with this when it comes to furnishing railway tonnage, and the fact that "raw mine products" constitute over one-half of all the carload tonnage handled by United States railways is a feature that should be kept well to the fore in any discussion of the Canadian railway problem.

When a new mine is developed in the north, a new community is established. Agricultural land in the vicinity comes under cultivation and pioneer farmers find a ready, high price, cash market for their produce. Mining now provides and will continue to provide the incentive that draws the venturesome northward. The colonization and opening up of Northern Ontario is largely dependent upon the development of our mining industry and Provincial and Dominion Governments must recognize this fact.

From North Bay and Sudbury to near the Manitoba boundary, iron mining must play no small part in the general plan of Canada's development. Providing our iron ore from our own resources is in itself a splendid and worthy objective, but after all, in a broad way, it may be considered as a means to an end. If in attaining this objective we can open up, colonize, and develop this vast territory, so little known and so little developed, we can assist in solving our railway problem, we can bridge the great gap between Eastern and Western Canada, and we can go far towards consummating the hopes and aspirations of those responsible for Confederation.

What Has Been Done to Further the Canadian Iron and Steel Industry

With the object of establishing an iron and steel industry in Canada, the Dominion Government, in 1884, offered to pay a bounty of $1.50 per ton of pig iron produced by Canadian furnaces from domestic ore. In 1895, a similar bounty was offered for the production of puddled bars, and steel billets and ingots. Progress was disappointing, and in 1898 a bounty of $3.00 per ton was made payable on pig iron, puddled bars, steel billets and ingots, and also a bounty of $2.00 per ton of pig iron produced from foreign ores. This did stimulate the industry, and progress was rapid.

In 1904 the bounty was made applicable to the production of rolled round wire rods and certain other manufactures of steel, and in 1909 to pig iron and steel produced by the electric process. From time to time the amount of the bounty was varied, and in 1912, after having paid out $17,396,434 in establishing the industry, all forms of direct Government assistance were withdrawn.

The fact that the assistance by bounty, originally intended for the iron mines, had passed to the furnace operators, has previously been mentioned. However, a Canadian iron and steel industry had been firmly established and to good purpose.

Recommendations

We, the Ontario Iron Ore Committee, unanimously recommend and urge:—

(1) That the Province of Ontario provide a bounty of one cent per unit of iron on each long ton of merchantable iron ore, natural or beneficiated, produced and actually marketed from Ontario deposits, and that such bounty be available to Ontario producers of merchantable iron ore for a period of ten years.

(2) That Section 111a, in The Mining Act of Ontario, be repealed.

(3) That a properly qualified geologist be permanently assigned to the work of studying and reporting on Ontario iron ore deposits.

(4) That a mining engineer be retained and charged with keeping the Department of Mines continuously in touch with improvements made in the art of ore dressing, concentrating, and sintering of low-grade iron ores, and that by co-operation with the authorities of the University of Toronto, sufficient equipment should be provided to enable such mining engineer to test any of these reported improvements in their practical application to our own Ontario ores.

Bonus

Many people believe that any industry that must be artificially supported by bonuses, or in some other way, is unworthy of that assistance. Yet in devious ways assistance is being given to nearly every industry. Experimental farms are operated by the governments to give guidance to the farmer. Thoroughbred stock is distributed at public expense. To perpetuate fishing, hatcheries are maintained. The credit of the province has been pledged to provide cheap power for the manufacturer. These are but a few of the examples that could be used to illustrate the point that bonus or bounty is known under many names.

Numerous plans have been suggested for the best way in which the Government might supply the necessary impetus to get iron ore mining in Ontario under way. Apart from the idea of direct bonus on actual production and sale of iron ore, they are all somewhat similar, in that they would involve the risking of public funds in ventures that may or may not prove financially successful. In the case of failure where direct financial assistance had been given to the producer by the Government, not only would it mean a monetary loss to Ontario, but the Government itself would be involved in the failure and the future of the industry jeopardized to that extent. Moreover, if direct assistance were granted to any one producer, every iron ore prospect, little or big, would expect similar treatment. Friction and chaos would result.

Without attempting, then, to cloak our recommendation in the habit of some paternalistic experiment of questionable value, we have bluntly and directly advocated a bonus, because assistance will be available to all who produce and actually market iron ore from Ontario deposits, and at no time will the province be involved in unsuccessful development.

With the bonus as an incentive, the best brains available will be turned upon this problem. The relative merits of the different iron ore deposits in the province will be worked out upon a practical, commercial basis, and we believe that before many years have passed, Ontario will be supplying her furnaces from her own resources.

Reason for One Cent per Unit Bonus

We have stated that certain siderite and high-grade magnetic iron ores can probably now be mined and beneficiated at a cost approximately equal to their market value, but that under such conditions there is no incentive for capital to enter the field. The amount of bonus stipulated, namely, one cent per unit of iron, is, in our opinion, the minimum necessary to interest capital in the venture. Even this amount may not be sufficient to stimulate commercial production from our low-grade magnetic iron ore deposits requiring fine grinding before concentration. Then, again, on every ton of iron ore imported and furnaced in Ontario, we pay in taxes and exchange to another country, approximately the same amount. Surely it is better that this money should stay in our own province and be used to build up and develop the industrial and economic life of Ontario.

Reason for Stipulating Ten Years

If our deductions, based largely upon statistics referred to in Chapter III, are correct, we should have our own iron ore industry firmly established before ten years have passed. By that time, the price of iron ore will probably be considerably higher than it is to-day, by reason of depletion and control of the naturally high-grade iron deposits in the United States Lake Superior iron ore district. Then, again, it takes time to investigate the relative merits of the different deposits and it takes additional time to equip and develop a mine and provide a beneficiation plant. If at the end of even three years, Ontario, under the stimulus of a bounty, is providing appreciable quantities of merchantable iron ore, we may consider ourselves fortunate. This means that the bounty will be actually available to producers for only about seven years.

Why Section 111a of The Mining Act of Ontario Should Be Repealed

To produce beneficiated iron ore, even with the assistance of the bonus recommended, at a cost that will permit it to be marketed in competition with other ores, production must be on a comparatively large scale. Producers must be free to market their product wherever an opportunity offers, either in Canada or on foreign markets. If we can export a certain amount of this ore, so much the better for Ontario and Canada.

To open up our iron mines, foreign capital will probably be required, and investors naturally will ask for a definite and permanently clear understanding that their title is secure and that they will be permitted to develop any and all markets available.

A Special Iron Ore Geologist

This recommendation is in no sense to be construed as a reflection on the work of our provincial geologists. As a matter of fact the present staff have established a brilliant record in their own field, and the precious metal mining industry is expanding so quickly that any suggestion that some one member be withdrawn from present work and assigned permanently to a study of our iron ranges, could only be considered as preposterous. We believe that the iron ore geologist should be an addition to the present staff.

Reason for Retaining a Mining Engineer to Study Beneficiation

Great progress has been made in methods of fine grinding, concentration, and sintering of low-grade iron ores during the past five or six years. During experimental work of this kind, much information may be obtained that is not available for publication. Failures are seldom described, yet a knowledge of these same vain attempts may be of very great value to the pioneer in another field.

If a mining engineer is retained for this work, as recommended above, he should be the friend and adviser of every operator seeking to produce iron ore in Ontario. Suitable and sufficient experimental laboratory equipment should be provided to enable him to check all reported processes and, where necessary, demonstrate them. The co-operative assistance of the University of Toronto would immediately place at the disposal of the Department of Mines much of this equipment, and if additional equipment were required, it should be furnished by the department.

If any further argument were required on this subject, we would refer the reader to what is being done in the State of Minnesota. Within its boundaries are positive reserves of high-grade iron ore estimated in excess of a billion tons. The people of that state have an intimate knowledge of the iron ore industry and a practical experience extending over many years, and they through their School of Mines and in co-operation with the Federal Government, are building an experiment station on the University campus that will cost when completed nearly $500,000. To operate and maintain this station, largely for research looking to the future utilization of their low-grade iron ores, the State and Federal Governments each provide $50,000 per year.

We are not suggesting anything so elaborate or expensive as the Minneapolis Experiment Station, but surely if a state so richly endowed in iron ore resources considers a solution of this problem so pressingly important, it is time for Ontario to undertake some work of a like nature.

Why the Dominion Government Should Help Establish This Industry

Finally, we are of the unanimous opinion that one half of the bonus recommended should be provided by the Dominion Government for the following reasons:—

(1) The active development of our iron ore resources and the enlarging of our steel industry, will be very effective in maintaining a favourable international trade balance.

(2) The colonization of Northern Ontario is largely dependent upon the mining industry, and settlement of that portion bordering the non-productive sections of our National railways is dependent largely upon development of our iron resources.

(3) Largely increased traffic may be obtained for the National railways from domestic production of iron ore, and it would not, perhaps, be unreasonable to suggest that the profit to be made by our publicly-owned railway would soon equal and in time exceed the proposed Dominion share of the bounty.

We have argued and attempted to prove that Ontario must in the near future stand prepared to provide her own iron ore for her own requirements. The results of our inquiry indicate that the task is possible. It is our belief that the bounty proposed is fair and equitable, and not more than necessary to attain the desired results. Undoubtedly Canada, as a whole, is as much concerned in the necessity of utilizing our own iron ore resources as Ontario or any of the other provinces.

CHAPTER I

PURPOSE OF APPOINTMENT OF IRON ORE COMMITTEE

The possibility of finding high-grade iron ore deposits and, if necessary, utilizing the present known low-grade iron ores, is a question that has long been discussed by the people of this province. Thoughtful men who have no direct interest in iron and steel enterprises, believing that so basic an industry is necessary to a well rounded development of our industrial and political activity, have joined those directly interested in a study of the situation with a view to building up in Canada iron ore mining enterprises that will supply all the ore required by our iron makers.

The serious situation of the iron and steel industry has also long been a matter of genuine concern to the Governments of Canada and this province, and the feeling grew that in a new country, endeavouring to become self-sustaining and independent of foreign supplies, such industries should, if necessary, be granted direct government assistance. As a result, in 1883, the Dominion Government offered a bounty on each ton of pig iron and steel made in Canada from Canadian ores; and in 1894 the Ontario Legislature established an Iron Mining Fund of $125,000, out of which producers or miners of iron ore in Ontario, smelted within the province, might be paid a bounty of $1 per ton on the pig metal product.

TOTAL BOUNTIES PAID BY THE GOVERNMENT OF CANADA SINCE 1884

Fiscal year	Pig iron	Puddled bars	Steel	Manufactures of steel[1]	Total
1884	$44,090	....	....	....	$44,090
1885	38,655	....	....	....	38,655
1886	39,270	....	....	....	39,270
1887	59,576	....	....	....	59,576
1888	33,314	....	....	....	33,314
1889	37,234	....	....	....	37,234
1890	25,697	....	....	....	25,697
1891	20,153	....	....	....	20,153
1892	30,294	....	....	....	30,294
1893	93,896	....	....	....	93,896
1894	125,044	....	....	....	125,044
1895	63,384	....	....	....	63,384
1896	104,105	$5,611	$59,499	....	169,215
1897	66,509	3,019	17,366	....	86,894
1898	166,654	7,706	67,454	....	240,814
1899	187,954	17,511	74,644	....	280,109
1900	238,296	10,121	64,360	....	312,777
1901	351,259	16,703	100,058	....	468,020
1902	693,108	20,550	77,431	....	791,089
1903	665,001	6,702	729,102	....	1,401,805
1904	533,982	11,669	347,990	$15,321	908,962
1905	624,667	7,895	676,318	231,324	1,540,204
1906	687,632	5,875	941,000	369,832	2,004,339
1907	385,231	312	575,259	338,999	1,299,801
1908	863,817	....	1,092,201	347,135	2,303,153
1909	693,423	....	838,100	333,091	1,864,614
1910	573,969	....	695,752	538,812	1,808,533
1911	261,434	....	350,456	526,858	1,138,748
1912	....	....	....	166,750	166,750
Totals.....	$7,707,648	$113,674	$6,706,990	$2,868,122	$17,396,434

[1] $127,755 was paid on angles and plates between 1904 and 1906; the rest on rods.

For a time, about the late nineties, Eastern Ontario gave promise of ultimately becoming a large iron ore producer. However, upon development, the ores were found to be rather low in grade and comparatively small in extent, and to contain certain objectionable impurities. As a much more desirable ore was available from the Lake Superior district of the United States, production in Ontario gradually grew less and less.

The following table shows the production of pig iron; the ore used, foreign and domestic; and the bounties paid by Ontario during the years 1896 to 1905 inclusive, or until the Iron Mining Fund was exhausted.

CONSUMPTION OF IRON ORE IN ONTARIO, 1896–1921

Year	Native ore smelted		Foreign ore smelted		Total ore smelted	Pig iron made	Amount Ont. Govt. bounty paid
	tons	per cent.	tons	per cent.	tons	tons	
1896	15,270	30.86	35,868	70.13	51,138	28,302	$4,000
1897	2,778	7.38	34,722	92.62	37,500	24,011	2,603
1898	20,968	27.22	56,055	72.77	77,023	48,253	8,647
1899	24,498	22.25	85,542	77.74	110,040	64,749	12,752
1900	22,887	22.72	77,805	77.27	100,692	62,386	6,737
1901	109,109	56.09	85,401	43.89	194,510	116,370	25,000
1902	92,883	49.69	94,079	50.31	186,962	112,687	25,000
1903	48,092	31.81	103,137	68.19	151,229	87,004	25,000
1904	50,423	22.56	173,182	77.44	223,605	127,845	15,236
1905	61,960	13.90	383,459	86.10	445,419	256,704	25
1906	101,569	20.40	396,463	79.60	498,032	275,558	......
1907	120,156	23.60	388,727	76.30	508,883	286,216	......
1908	170,215	33.20	342,747	66.80	512,962	271,656	......
1909	220,307	28.80	543,544	71.20	763,851	407,013	......
1910	143,284	17.40	678,890	82.60	822,174	447,351	......
1911	67,631	7.40	848,814	92.60	916,445	526,610	......
1912	71,589	6.50	1,062,071	93.50	1,133,660	589,593	......
1913	132,708	10.90	1,095,561	89.10	1,228,269	648,899	......
1914	163,779	17.80	752,560	82.20	916,339	556,112	......
1915	293,305	32.00	623,094	68.00	916,399	493,400	......
1916	215,366	16.90	1,056,810	83.10	1,272,176	699,202	......
1917	94,318	7.10	1,221,881	92.90	1,316,199	691,233	......
1918	99,852	6.75	1,400,085	93.25	1,499,937	751,650	......
1919	97,514	7.50	1,201,834	92.50	1,299,348	623,586	......
1920	152,176	10.40	1,341,661	89.60	1,493,837	748,173	......
1921	113,083	13.50	723,858	86.50	836,941	438,013	......
Totals...	2,705,720	....	14,807,850	....	17,513,570	9,382,576	$125,000
Average per year	104,000	15.50	569,500	84.50	673,500	....	....

While it was primarily intended that the bounty paid should be an incentive to the development of our own iron ore deposits, it failed in this respect. The bounty was, however, a big factor in the development of our iron and steel making industry.

The development of the steel industry was indeed fortunate, because during the war the production of munitions was a matter of supreme importance to the Allied cause and to the economic position of Canada. Just when Canada's

manufacturers had mastered the details of construction and equipped their plants for mass production, the United States joined the Allies and requisitioned all the shell steel their furnaces were capable of producing. Canada was immediately placed in the position where she must either produce her own shell steel, or admit her inability to produce munitions. This type of steel had never been produced in Canada, and many, with no mean knowledge of the industry, said it was impossible to produce it. However, where there is a will there is a way, and Canadians did produce shell steel, and munitions continued to go forward in ever-increasing quantities until the end of hostilities.

Our knowledge of the steel industry and our facilities for the practical application of this knowledge during the war were, in a large way, the result of the early Government assistance to our iron and steel industry, and the splendid record established during the war must ever reflect the foresight and business ability of those who, in the early days, determined that such an industry was essential to Canada's development.

The following companies have furnaces in Ontario which were available for use in 1922:—

Algoma Steel Corporation, Sault Ste. Marie, Ontario.—Has 4 furnaces with combined capacity of 1,450 tons pig iron daily. During 1922 operated one furnace in January, two for the next seven months, and one only for the remainder of the year.

Atikokan Iron Company, Port Arthur, Ontario.—Has one furnace of 175 tons daily capacity, which has been idle since 1911.

Canadian Furnace Company, Port Colborne, Ontario.—Has one furnace of 325 tons daily capacity.

Midland Iron and Steel Company, Midland, Ontario.—Has one furnace with capacity of 120 tons per day. Idle since February, 1922.

Parry Sound Iron Company, Midland, Ontario.—Has a furnace at Parry Sound of 90 tons daily capacity. Idle since October, 1919.

Standard Iron Company, Deseronto, Ontario.—Has one furnace of 60 tons daily capacity, that has not been in operation since June, 1919.

Steel Company of Canada, Hamilton, Ontario.—Is operating two furnaces with combined capacity of 750 tons daily.

The Canadian Steel Corporation.—Has erected at Ojibway, near Windsor, two large blast furnaces, but has not yet operated them.

Need for New Study of the Iron Ore Situation

During the war the Helen mine, the only hematite producing property in Ontario, was exhausted, and the siderite deposits at the Magpie were nearly exhausted. In the financial depression following, the Moose Mountain Company closed down, and not one Canadian iron mine found it possible to continue profitable production. With the closing of the Magpie early in 1921, iron mining in Canada ceased, and Canadian furnaces drew their supplies entirely from foreign countries.

This condition forced Canadians into a realization of their position. The Advisory Council for Scientific and Industrial Research were the first to tackle the problem. The council appointed a sub-committee composed of:—

J. G. Morrow, *Chairman*
Frank D. Adams, D.Sc., LL.D., F.R.S.
Lloyd Harris
Geo. A. Guess, M.A.
Arthur Surveyer, B.A.Sc.
J. B. Tyrrell, B.Sc., M.A.
Th. Denis, B.Sc.
H. E. T. Haultain, C.E.
A. Stansfield, D.Sc., F.R.S.C.
A. Mailhiot, B.A.Sc.
C. V. Corless, M.Sc., LL.D.

Conference Called by Minister of Mines

As a beginning, Hon. Harry Mills, Minister of Mines, called a conference of those interested in the question, for July 5th, 1922, and issued invitations which were accepted by the following:—

G. J. MacKay, Queen's University, Kingston.
W. M. Goodwin, Canadian Mining Journal, Gardenvale.
W. H. Collins, Geological Survey, Ottawa.
P. A. Leitch, Hematite Ore Co., Nipigon.
Henry Dreany, Consolidated Iron & Steel Co., Toronto.
Rinaldo McConnell, Perth.
J. N. McKendrick, Belcher Island Iron Mines, Galt.
E. LeDuc, Belcher Island Iron Mines, Galt.
J. G. Morrow, The Steel Co. of Canada, Ltd., Hamilton.
G. A. Guess, University of Toronto, Toronto.
Geo. E. Kidd, Ottawa.
Boyd A. C. Caldwell, Perth.
Thos. B. Caldwell, Perth.
F. D. S. Robertson, Toronto Power Company, Toronto.
B. Neilly, Ontario Mining Association, Toronto.
H. E. T. Haultain, University of Toronto, Toronto.
W. Rowland Cox, Moose Mountain, Ltd., New York City.
J. D. Jones, Algoma Steel Corporation, Sault Ste. Marie.
Cyril W. Knight, Department of Mines, Toronto.
Geo. S. Cowie, Algoma Steel Corporation, Sault Ste. Marie.
G. G. Ommanney, C.P.R., Montreal.
Geo. C. McKenzie, Canadian Institute of Mining and Metallurgy, Montreal.
Col. J. A. Currie, M.P.P., Parry Sound Iron Co., Toronto.
Cyril T. Young, C.N.R., Toronto.
C. Price-Green, C.N.R., Toronto.
Chas. McCrea, M.P.P., Sudbury.

Also present at the conference were:—

T. W. Gibson, Deputy Minister of Mines, Toronto.
Hon. H. Mills, Minister of Mines, Toronto.

To those assembled the minister presented the following subjects for discussion:—

(1) The extent of the iron ore deposits of Ontario. Are they sufficient to sustain a native blast furnace industry of importance?

(2) The kind and quality of the deposits: (*a*) The iron ores of Eastern Ontario. (*b*) Deposits of banded magnetite, or mixed magnetite and hematite. (*c*) Siliceous hematite. (*d*) Siderites. (*e*) Bog iron ores.

(3) (*a*) The applicability of magnetic concentration methods for low-grade magnetites, and subsequent briquetting or nodulizing. (*b*) Process for increasing the metallic content of siliceous hematites. (*c*) The roasting and nodulizing of siderites.

(4) Are all or any of the above, or other methods of beneficiation within permissible limits of cost?

(5) How far can a market be found in Ontario for beneficiated Ontario ores?

(6) Is there a market for more than the present pig iron product of Ontario? If so, where?

(7) Can the problem be attacked by adapting a method of reduction to low-grade ores, rather than by treating the ores so as to make them amenable to present blast furnace practice?

(8) Any aspects of the question not enumerated above.

Resolutions Passed by Conference

Throughout the conference there was displayed an earnestness and a tolerance for the other man's opinion that indicated a clear appreciation of the difficulties to be faced and of the still greater importance of finding, without delay, a satisfactory solution of the problem. Some present were thoroughly convinced that the only practical way the Government could assist the industry was by giving direct bonuses for the production of iron ore, and accordingly they presented the following resolutions:—

Whereas it is in the best interests of the Province and of the Dominion that the iron ore producing industry of this country be materially assisted through Government aid, a total cessation of iron ore production in Canada having now occurred;

And whereas high-grade ores of the Mesabi range are being eliminated yearly and American iron ore interests are erecting beneficiating and treating plants, similar to the successful plants in Europe, costing in one instance as high as $4,000,000, handling lower grade ore than the natural contents of our Canadian ore;

And whereas the Canadian steel industry was only made possible through a reasonable assistance over a period of sixteen years, and warranted the construction of steel mills of large capacity, and consequent lower overhead, which in time of stress provided 55 per cent. of the shell steel made into munitions by Canadian industry;

And whereas the American railways derive 55 per cent. of their freight traffic from the mining industry, and a large percentage of this is due to the carrying of immense quantities of iron ore, and the coke and coal used in the industry; and our Canadian railways, particularly the National railways, traversing as they do so many of the important iron ranges, would benefit probably more than the iron industry itself from the movement of the 2,000,000 tons of iron ore which is now imported annually for consumption in our Canadian mills;

And whereas iron and steel products are used almost exclusively for agricultural implements, automobiles, etc., and the last Dominion statistics published show that the yearly cost of raw material alone for the manufacture of agricultural machinery and automobiles amounted to $40,000,000, and the raw material used by the 1,064 foundries and steel mills in Canada to $238,000,000, and these industries are growing so tremendously that it becomes a national duty to provide the raw material within the confines of our own country;

And whereas the granting of assistance would, particularly in the first few years, involve a small annual outlay, but the large returns and impetus to industrial activity would be immeasurable because it would cause the retention in Canada of large amounts of money now being sent out of the country for the purchase of foreign ores, and also the employment and investment of British and American capital to develop iron ore bodies;

And whereas the production of Canadian iron ores for Canadian steel mills now erected will complete the national equipment for the production of iron and steel and place Canada in a position of greater independence, and assure the blast furnace and steel works their raw material which will enable Canada to carry on within the confines of her own country the complete production of iron and steel for the manufacture of our farm machinery, automobiles, trucks, and other manufactured products;

And whereas there is a gap between the cost at which Canadian iron ore can be mined under present conditions and the prices that Canadian smelters can afford to pay and market their product, and this condition will continue to exist unless assurance is given that aid will be available to an extent that will warrant the erection of the necessary beneficiation plants, and that such aid will be received when earned during the years these mines are developing tonnage in sufficient quantities to carry their overhead and operate economically;

Now therefore be it resolved as follows: That the Provincial and Dominion Governments render tangible assistance on all Canadian iron ore mined and marketed to be paid monthly to mine operators, reckoned when the ore is milled or treated, the long ton weights going into milling, treating or the beneficiation process, and when not requiring milling or treating, on the long ton, based on shipping weights going to furnaces; said assistance being in force for a fifteen year period, necessary to the thorough establishment of the home production of iron ore in Canada.

This resolution was passed, but there were many present who were disinclined to subscribe to this as the only solution of the problem, at least not until a great deal of additional information was made available. At the conclusion of the conference, the following resolutions were presented and unanimously passed:—

(1) The extent of the iron ore deposits of Ontario. Are they sufficient to sustain a native blast furnace industry of importance?

Resolved: *That the known iron ore resources of Ontario are sufficient to support an important iron and steel industry, providing that these ores are beneficiated.*

(2) The kind and quality of the deposits: (*a*) The iron ores of Eastern Ontario. (*b*) Deposits of banded magnetite, or mixed magnetite and hematite. (*c*) Siliceous hematite. (*d*) Siderites. (*e*) Bog iron ores.

RESOLVED: *We believe that extensive drilling exploration of the known available iron ranges may prove the existence of valuable ore deposits which would not require beneficiation.*

(3) (*a*) The applicability of magnetic concentration methods for low-grade magnetites, and subsequent briquetting or nodulizing. (*b*) Process for increasing the metallic content of siliceous hematites. (*c*) The roasting and nodulizing of siderites.

This subject does not require a resolution.

(4) Are all or any of the above, or other methods of beneficiation within permissible limits of cost?

RESOLVED: *Providing that the market can absorb a large tonnage of beneficiated ore at a satisfactory price, both magnetic separation and calcining of siderites are recommended.*

(5) How far can a market be found in Ontario for beneficiated Ontario ores?

(6) Is there a market for more than the present pig iron product of Ontario? If so, where?

RESOLVED: *That these questions should be left to a special committee.*

(7) Can the problem be attacked by adapting a method of reduction to low-grade ores, rather than by treating the ores so as to make them amenable to present blast furnace practice?

(8) Any aspects of the question not enumerated above.

RESOLVED: *That the Ontario Government appoint a committee, consisting of at least a geologist or mining engineer, a blast furnace operator or metallurgist, and a transportation expert, to make special inquiry concerning all phases of this question, including ore deposits, mining, beneficiation, smelting and special methods of reduction.*

In his closing remarks to the conference, the Minister of Mines stated that the recommendations presented would have the early consideration of the Government, and that the appointment of a committee to investigate and report on the whole subject might reasonably be expected.

Appointment of Iron Ore Committee

On October 25th, 1922, the following Order in Council was passed:—

"Upon the recommendation of the Honourable the Minister of Mines, the Committee of Council advise that the persons mentioned below be appointed to make research, investigate, and report upon the extent and quality of the deposits of low-grade iron ores in Ontario, the best commercial methods of beneficiating the same, and generally, what steps or measures should be adopted to enable the low-grade and other iron ores of this province to be utilized in the production of pig iron and steel:

J. G. MORROW,	Hamilton
LLOYD HARRIS,	Brantford
G. A. GUESS,	Toronto
H. E. T. HAULTAIN,	Toronto
GEO. S. COWIE,	Sault Ste. Marie
R. J. HUNT,	Montreal

The work of such committee to be under the general supervision of the minister, and the expenditures incurred, and the remuneration of the members of the committee to be paid out of the appropriation for Research Work, Vote 107, Item 13, Estimates 1922-23."

Of the six members appointed, four were already members of the sub-committee of the Advisory Council for Scientific and Industrial Research. The latter council immediately acquiesced in the new arrangements and placed at the disposal of the Ontario Iron Ore Committee the results of their investigation up to that time; the grateful acknowledgment of this practical co-operation and assistance is herewith recorded.

Toward the end of October, the Iron Ore Committee was organized and the work commenced.

CHAPTER II

AVAILABLE SOURCES OF IRON ORE FOR ONTARIO FURNACES

Perhaps no metal in the earth's crust has a more general distribution than iron. However, deposits of merchantable iron ores, or iron ores that will permit a profit to be made from their commercial reduction to the metallic state, are comparatively scarce.

At the World's Geological Congress held at Stockholm, Sweden, in 1920, the known world's deposits of merchantable iron ore were listed as follows:—

	Actual reserve	Potential reserve
	tons	tons
Europe	12,032,000,000	41,029,000,000
America	9,855,000,000	81,822,000,000
Australia	136,000,000	69,000,000
Asia	260,000,000	457,000,000
Africa	125,000,000	Enormous

The chief centres of actual ore reserves were indicated as follows:—

CHIEF CENTRES OF IRON ORE RESERVES

	Ore	Iron content
	tons	tons
Lorraine (Germany, France, Luxemburg, and Belgium)	5,650,000,000	1,865,000,000
North Sweden	1,035,000,000	670,000,000
Bell Island, Newfoundland	3,635,000,000	1,961,000,000
Lake Superior region	3,500,000,000	2,000,000,000
Cuba	1,903,000,000	856,800,000
Minas Geraes Province, Brazil	[1]5,710,000,000	3,055,000,000

[1]Potential.

It will be seen at once that the Lake Superior deposits are comparatively large. Now the cost of transportation involved in the process of mining, furnacing, and laying down the finished article where it is to be used, absolutely limits the area for distribution of the ore from any iron deposit. Under present conditions, Ontario is well within the limits for the commercial distribution of ore from the Lake Superior deposits. If rail rates were measurably reduced, some of the beneficiated magnetites from the New England states might gain entry to the Ontario markets. If the St. Lawrence deep waterways scheme should succeed, a certain tonnage of Wabana ore would undoubtedly be used in Ontario furnaces. But these possibilities are at the present time somewhat remote, and since the Ontario Iron Ore Committee set out to investigate this problem from the commercial, present-day standpoint, we are, in a practical way, concerned only with conditions as they exist within the area of profitable distribution for Lake Superior ores.

The Lake Superior Area

In a later chapter a detailed description of the several deposits within this area will be found; but in order that the reader may gain some idea of their relative magnitude, the following figures are here presented to show the estimated reserves of merchantable iron ore as of January 1st, 1920, prepared by Mr. R. C. Allen:—

IRON ORE RESERVES OF THE LAKE SUPERIOR REGION IN THE UNITED STATES, JANUARY 1st, 1920. ESTIMATES COMPILED BY R. C. ALLEN, FROM THE MOST RELIABLE DATA AVAILABLE. SILICEOUS ORES NOT INCLUDED. BESSEMER AND NON-BESSEMER ORES INCLUDE PRESENT COMMERCIAL GRADE ONLY.

Source	Assured Ore			Probable Ore			Total Assured and Probable Ore		
	Bessemer	Non-Bessemer	Total assured	Bessemer	Non-Bessemer	Total probable	Bessemer	Non-Bessemer	Total assured and probable
	tons	tons	tons	tons	tons	tons	tons	tons	tons
MINNESOTA									
Mesabi range[1]	330,431,666	938,634,349	1,269,066,015	99,129,500	281,590,300	380,719,800	429,561,166	1,220,224,649	1,649,785,815
East Mesabi[2]	...	...	...	[2]300,000,000	...	[2]300,000,000	300,000,000	...	300,000,000
Vermilion range[3]	15,000,000	Negligible	15,000,000	15,000,000	Negligible	15,000,000	30,000,000	...	30,000,000
Cuyuna range[4]	Negligible	55,846,435	55,846,435	Negligible	100,000,000	100,000,000	...	155,846,435	155,846,435
Total	345,431,666	994,480,784	1,339,912,450	414,129,500	381,590,300	795,719,800	759,561,166	1,376,071,084	2,135,632,250
WISCONSIN[5]									
Gogebic-Florence-Mayville-Baraboo	2,500,000	19,000,000	21,500,000	15,000,000	41,000,000	56,000,000	17,500,000	60,000,000	77,500,000
MICHIGAN[6]									
Gogebic range	14,384,638	50,178,365	64,563,003	70,000,000	180,000,000	250,000,000	84,384,638	230,178,365	314,563,003
Marquette range	8,504,258	62,129,111	70,633,369	15,000,000	100,000,000	115,000,000	23,504,258	162,129,111	185,633,369
Iron River-Crystal Falls district	...	54,632,863	54,632,863	...	150,000,000	150,000,000	...	204,632,863	204,632,863
Menominee district	2,115,811	7,147,809	9,263,620	2,000,000	15,000,000	17,000,000	4,115,811	22,147,809	26,263,620
Total	25,004,707	174,088,148	199,092,855	87,000,000	445,000,000	532,000,000	112,004,707	619,088,148	731,092,855
Grand total	372,936,373	1,187,568,932	1,560,505,305	516,129,500	867,590,300	1,383,719,800	889,065,873	2,055,159,232	2,944,225,105

[1] Assured ore, Mesabi range, based on estimates of Minnesota Tax Commission. R. C. Allen adds 30 per cent. for probable ore.
[2] East Mesabi magnetite concentrates above depth of 50 feet in present explored area, by W. G. Swart (also quoted in Iron Trade Review).
[3] Assured and probable ore by R. C. Allen.
[4] Assured ore by Minnesota Tax Commission. Probable ore by R. C. Allen.
[5] By W. O. Hotchkiss, State Geologist of Wisconsin.
[6] Assured ore is the estimate by the Michigan Tax Commission of "developed and prospective" ore. Probable ore by R. C. Allen. Dr. C. K. Leith estimates for Gogebic, in addition to "present reserves", 250,000,000 tons above 3,000 foot level.

If we deduct from this total the tonnage shipped from the same ranges in 1920 and 1921, we have left an estimated reserve of 2,860,841,833 tons of merchantable iron ore.

The question that naturally follows is, how soon will these reserves be depleted? So long as these Lake Superior ores are available on the open markets, beneficiated ores, prepared and produced with greater effort, must compete against the cost of production of naturally merchantable ores.

Statistics indicate a constantly increasing per capita consumption of iron ore, but with export business in a somewhat demoralized condition, it would be difficult to predict this increase. Moreover, the extraordinary conditions during the war period must be given consideration. For these reasons, in calculating the average consumption of iron ore in Canada and the United States, under present conditions, we have confined our survey to the records of the last three years available, viz., 1919, 1920, and 1921.

IMPORTS OF IRON ORE INTO UNITED STATES FROM ALL COUNTRIES OTHER THAN CANADA

From figures prepared by the U.S. Geological Survey

Year	Cuba	Spain	Norway and Sweden	Other European countries and England	French Africa	Other countries	Total	Yearly average
	tons	tons	tons	tons	tons	tons	tons	tons
1919....	321,753	63,737	67,966	6,556	3,981[1]	85	464,078	....
1920....	889,852	69,915	65,689	4,696	193,829[2]	15,391	1,239,372	....
1921....	123,222	40	143,234	2,344	22,696[3]	14,457	305,993	....
Total ..	....	....	....	....	....	....	2,009,443	....
Yearly average.	....	....	....	....	....	....	....	669,814

[1] British West Africa.
[2] Includes 34,940 tons from Morocco.
[3] Includes 14,360 tons from Morocco.

IMPORTS OF IRON ORE INTO CANADA FROM ALL COUNTRIES OTHER THAN THE UNITED STATES

Figures from the Department of Statistics, Ottawa

Year	United Kingdom	Newfoundland	Other countries	Yearly average
	tons	tons	tons	tons
1919..............	....	529,232	....	....
1920..............	....	616,287	22,009	....
1921..............	....	137,032	7,123	....
Yearly average...	....	....	....	437,228

SUMMARY COVERING 1919–1920–1921

	Tons	Per cent.
Average production of U.S. mines outside Lake Superior district........	7,412,394	13.77
Average production by all mines in Lake Superior district.............	44,034,532	81.70
Average tonnage imported by U.S. from all countries other than Canada	2,009,443	3.72
Average tonnage imported by Canada from all countries other than United States..	437,228	0.81

IRON ORE PRODUCED BY UNITED STATES MINES OUTSIDE THE LAKE SUPERIOR DISTRICT

Year	New England	New Jersey	New York	Penn.	Georgia	Alabama	N.C.	Tenn.	Va.	Mo.	Other States	Total	Yearly average
	tons	tons	tons	tons	tons	tons	tons	tons	tons	tons	tons	tons	tons
1919	14,893	404,428	871,495	627,167	71,224	5,053,035	56,778	283,792	305,096	53,856	694,851	8,438,615	....
1920	10,339	431,567	920,009	734,383	104,611	5,894,011	71,810	375,538	320,924	54,994	741,330	9,659,416	....
1921	4,100	58,589	469,988	146,649	5,556	2,876,141	2,583	25,709	74,021	36,550	439,261	4,139,147	....
Yearly average	....	....	....	....	....	....	....	....	....	....	....	....	7,412,394

IRON ORE PRODUCED BY ALL MINES IN THE LAKE SUPERIOR DISTRICT

Year	Marquette range	Menominee range	Gogebic range	Vermilion range	Mesabi range	Mayville range	Baraboo range	Cuyuna range	Total U.S. mines	Canadian mines	Grand total	Yearly average
	tons	tons	tons	tons	tons	tons	tons	tons	tons	tons	tons	tons
1919	2,992,212	4,446,412	6,229,560	929,049	32,003,169	92,819	....	1,859,200	48,552,421	167,904	48,720,325	....
1920	4,608,323	6,569,384	8,763,332	1,007,435	37,147,705	78,544	51,027	2,191,528	60,417,278	114,189	60,531,467	....
1921	1,116,560	1,584,403	2,336,493	869,313	16,349,896	52,413	....	489,500	22,798,578	53,227	22,851,805	....
Yearly average	....	....	....	....	....	....	....	....	....	....	....	44,034,532

Estimated Life of Lake Superior Iron Mines

Deducting the 1920 and 1921 shipments from the Lake Superior districts, we can calculate an assured ore reserve of approximately 1,477,000,000 tons, and if the average production from this district is taken at 45,000,000 tons, it is apparent that the positive ore reserves will be exhausted in about thirty-two years. If we include the estimated probable ore reserves, this period is increased to a little more than sixty years, less, in each case, such period as will compensate for a gradually increasing production to care for a growing per capita consumption of iron and steel products and any wider distribution that would result from decreased transportation rates.

Basis of Estimation of Ore Reserves

Now these are very general deductions, and the advisability of including probable ore will undoubtedly be questioned by many who are not familiar with the method of mine taxation as practised in the State of Minnesota, where most of these reserves are listed.

In practice the state has found it possible to calculate the ore reserves on any one property with fair accuracy. Knowing the tonnage and average grade available from any particular property, the average selling price at Lake Erie points is taken. From this is deducted the cost of transportation from the mine and the average cost of mining such ore in the state. The remainder, with no deduction for royalties that may be payable, is assumed to be the value of the ore reserves per ton. The next step is to calculate the probable life of the mine, and from that the average annual production. With this data the present worth is calculated and one half such sum is the assessed value of the property for taxes levied by state, county, and municipalities.

Revenue is so easily raised in this manner that the municipalities, in some cases, appear to vie with each other as to which shall make the most riotous expenditure. Taxes are increasing. In periods of normal activity in the iron and steel industry, they must in all fairness be considered onerous, and in some periods of depression excessive.

However, we are interested only in the results arising from such methods. In the first place, every property is anxious to ship without delay the more easily obtained ore, so that their assessment may thereby be reduced. The principles of conservation are set at naught. Secondly, the natural incentive to develop positive ore reserves beyond immediate requirements is stifled by the knowledge that increased ore reserves are penalized by an increased burden from taxation.

Some of the large and well financed companies can bear with this situation, serene in the knowledge that eventually the public must pay the taxes through increased prices for iron ore. Others, not so strong, are forcing production, and this has undoubtedly tended to keep the price of iron ore around present levels. When those deposits of what may now be called "distress ore" are exhausted, the markets will probably move upward. Furnaces in Ontario will experience higher prices for iron ore and an increasing difficulty in obtaining suitable grades. The compensating factor is that as prices generally move upward, the difficulties now involved in the production of beneficiated iron ore will grow less and less.

Coming back to our consideration of ore reserves, it will now be apparent to the reader that there is no disposition on the part of the mine owners to over-estimate their positive ore reserves, and that on the basis of our former assumptions, thirty-two years is a reasonable estimate.

Only a Very Small Part of Lake Superior Ore is Available to Ontario Users

If all these reserves were owned by one company interested only in the sale of iron ore, our discussion of the subject might end here; but, unfortunately for us, the situation is not so simple.

Of the 1,340,000,000 tons of assured ore estimated in Minnesota in 1920, over sixty per cent. was the property of one large steel company. Of the remaining forty per cent., a large part is owned by other large steel corporations. A comparatively small portion of the estimated reserve remains outside of the control of companies who require the ore for their own furnaces, and upon this small portion of "free ore" Ontario is dependent for her requirements. The volume of free ore might be calculated with reasonable accuracy, but no real purpose would be served since it is the policy of the large consuming companies to purchase or lease when possible. The supplies available to open market, from whence we draw our requirements, must continue to dwindle at an accelerating pace, and long before the conclusion of the estimated thirty-two year period, we must provide for our own requirements from our own resources, or pay a profit to the United States producers of iron ore that will place our steel companies in Ontario in a position where they will experience real difficulty in competition against foreign prices.

We have here sought to indicate:—

(1) That in a study of this problem we are practically concerned only with the area supplied with iron ore from the Lake Superior deposits.

(2) That there are manifest advantages to be derived from a further development of our iron and steel industry.

(3) That this industry is at present dependent upon a small, rapidly dwindling reserve of foreign ore.

(4) That the steel companies are so vitally interested in procuring, in Ontario, additional sources for the supply of their raw material, that their cooperation may be expected.

(5) That our best efforts are immediately required to the end that this problem may be solved and Ontario made, so far as possible, independent of foreign supplies.

CHAPTER III

LAKE SUPERIOR IRON ORE DEPOSITS

The Lake Superior iron ore deposits are found on the southern extremity of the great pre-Cambrian shield or basement formation that includes largely the north central part of Canada and of which only a relatively small area extends into the United States. The producing iron mines are in Minnesota, Michigan, and Wisconsin.

There are two main geological divisions. The first or lower formation being the Archean, which includes the Keewatin greenstones, schists, etc., and the Laurentian granites. The second division, the Algonkian, is superimposed upon the Archean and embraces the Keweenawan, and the Upper, Middle, and Lower Huronian, in the order named. The Huronian is composed chiefly of sedimentary rocks, with some igneous, intrusives and extrusives. The Keweenawan is for the most part made up of igneous rocks with some red sandstones and conglomerates.

TABLE SHOWING THE ROCK GROUPS IN THE LAKE SUPERIOR DISTRICT

Algonkian	Keweenawan
	Upper Huronian
	Middle Huronian
	Lower Huronian
Archean	Keewatin
	Laurentian

The iron formations occur in both the Keewatin and Huronian series of rocks. They are all very similar and consist of chert or quartz, iron oxide minerals, and relatively small amounts of other iron-bearing materials, such as iron carbonate. The secondary ore deposits are masses of iron ore which have been formed by concentration of iron ore from rocks rich in iron. This alteration is ascribed to action of underground waters. In favourable places the iron formation has been decomposed and ore deposits formed.

The size of such secondary iron deposits seems to have depended largely upon the structural relations of the iron formations and the presence of impervious rocks at the base of or embedded within the iron formation. These factors controlled and directed the flow of underground waters and consequently the alteration of the iron formation.

In a general way, these important iron deposits are found on the slopes or at the base of outstanding hills or ranges and are associated with pitching troughs of relatively impervious rocks.

Where the troughs are large and uniform, the alteration of the iron formation is more pronounced and the larger deposits of iron have been found. Where they are small, irregular, and broken, the alteration is less extensive and the ore deposits are comparatively small and erratic as to quality. These secondary ores were deposited in a hydrated condition, but have been partially dehydrated and may be classified as red, blue, and micaceous hematite and magnetite, the soft ones being hematite and limonite.

The primary deposits, so far as they represent iron ore, will be discussed under the Michipicoten area.

The iron mining districts in the Lake Superior area include the Vermilion, Mesabi, Cuyuna, Gogebic, Iron River and Crystal Falls, Florence, Baraboo, Menominee, and Marquette in the United States; and the Michipicoten and Moose Mountain in Ontario.

Vermilion Range.—This range lies in northeastern Minnesota and includes the towns of Tower, Soudan, and Ely. The ore occurs in narrow belts which are enclosed in Keewatin greenstone. The whole district is one of complex folding where the dip is very steep and the outcrops are small. The ores are hard, blue and red hematites.

Mesabi Range.—This range lies northwest of Lake Superior in the State of Minnesota and extends in an east and west direction for a distance of about 100 miles. The principal towns are Biwabik, Eveleth, Virginia, Chisholm, Hibbing, Naswauk, and Coleraine.

The iron formation is of the Upper Huronian and lies along the southern slope of a range dipping gently to the south and known as the Mesabi range.

The surface is covered with glacial drift, and rock exposures are rare. The slope of the iron formation is gentle, and the ore deposits, shallow as to depth, are mostly flat, having a comparatively large horizontal area.

In general the ore deposits are covered only by glacial drift, and open pit mining is characteristic of this range.

The impervious basement upon which the ore bodies are found, is formed by layers of slate or paint rock interbedded with iron formation.

The ores are mostly soft, hydrated hematites and limonites, varying in texture from very fine dust to hard, coarse, granular ore. Toward the western end of the range layers of sand are often encountered, interbedded with the ore, forming the so-called "sandy" ores which must be concentrated to bring them up to merchantable grades.

The Mesabi range is by far the most important iron producing district in the Lake Superior region. The depth in some cases exceeds 400 feet, but will probably average little more than 250 feet.

Cuyuna Range.—The Cuyuna range is located in the State of Minnesota, about 100 miles west of Duluth. The principal towns within this area are Deerwood, Crosby, and Brainerd.

Distinct topographical features are lacking. The surface is level, covered with a heavy mantle of sand.

Surface indications do not assist in the prospecting for ore, and the work of locating the deposits is largely dependent upon magnetic variation. Drilling has proved that the lines of magnetic variation are associated with belts of iron-bearing formation which trend in a northeasterly and southwesterly direction. The formation is interfoliated with slate and schist and is usually steeply tilted. In some localities igneous intrusive rocks are encountered. The iron formation is thought to belong to the Upper Huronian series of rocks and occurs in two belts, roughly parallel, known as the North and South ranges. The ore deposits are usually lenticular in form and erratic in outline. There has been little development beyond a depth of 360 feet.

Gogebic Range.—The Gogebic range is a narrow belt of iron formation which lies south of Lake Superior in Michigan and Wisconsin, the more important

though smaller part being in the former state. Among the principal towns in this area are Wakefield, Bessemer, Ironwood, and Hurley.

The most important iron formation is in Upper Huronian series. It is a narrow belt dipping toward the north with a crenulated outcrop due to a series of minor transverse folds. The iron formation rests upon Upper Huronian quartzite and is cut by igneous dikes which combine with the quartzite to form impervious troughs in which the ore bodies were concentrated. The ores are soft, red, and partially hydrated hematites with subordinate amounts of hard blue hematites.

Development has been carried to a depth of 2,300 feet at the Newport and Montreal mines.

Iron River, Crystal Falls, and Florence Districts.—The Iron River and Crystal Falls districts lie in Michigan, and the Florence district is in Wisconsin. The principal towns are Iron River, Crystal Falls, and Florence.

The iron formation is found in Upper and Middle Huronian. The ores are mostly soft red hematites, although in places they are hydrated and classified as limonite. Development has been carried to a depth of about 1,300 feet.

These districts are generally included with Menominee district, so far as production figures are concerned. The Iron River, Crystal Falls, Menominee, and Florence districts are the chief districts in the group which comprise the Menominee range.

Menominee District.—This district includes the towns of Iron Mountain and Norway and lies wholly in the State of Michigan. The iron formation is found in the Upper Huronian series and occurs in several narrow belts, all of which have a steep dip. The principal belt extends east and west for a distance of twenty miles and the important ore bodies rest on the Lower Huronian dolomite and are covered by Upper Huronian slate.

The ores are usually bluish-black hematites, though smaller bodies of red and brown banded hematites are found. Development has been carried to a depth of about 1,500 feet.

Marquette Range.—The Marquette range is comparatively small. It lies in the State of Michigan and derives its name from the City of Marquette. The principal towns are Ishpeming, Negaunee, Champion, and Republic.

The iron formation occurs in the Upper and Middle Huronian and the Keewatin division of Archean. The ores are mostly soft red hematites, although the hard micaceous hematites are important. Subordinate amounts of magnetite and limonite are found. The district is cross-folded, so that the ore bodies are irregularly distributed. In general the iron formation extends in an east and west direction, and the ore deposits that outcrop reach the surface on the middle or upper parts of the slopes.

These outcrops were conspicuous and led to the early discovery of the district. Some of the ore deposits are entirely beneath low-lying areas, but in these cases are surrounded by impervious rocks.

Development has been carried as deep as 2,470 feet.

Baraboo District.—This district cannot be definitely described as within the pre-Cambrian area, although the formation is in some respects similar to that found in Middle Huronian. It is located in south central Wisconsin, and its principal town is North Freedom.

The ores are hematites with soft, earthy, and hard, black and banded

siliceous phases. They are stratified and have the same strike and dip as the associated rocks, which dip at various angles from nearly horizontal to nearly vertical.

Michipicoten Range.—This range lies in Ontario on the northeastern shore of Lake Superior and includes the Helen and Magpie mines. The ore deposits were both found in the Keewatin series of the Archean. From the Helen mine there was produced until 1918, a hard, non-Bessemer hematite. Adjacent to the hematite area is a large and important body of siderite. Until March, 1921, the Magpie produced a siderite or iron carbonate ore which was calcined and nodulized to produce a commercial product.

The Magpie was developed to a depth of 581 feet.

Moose Mountain District.—This district is in Ontario. Moose Mountain mine is situated about twenty-five miles north of Sudbury. Here also the ore is found in the Keewatin series. The ore is a disseminated magnetite, running about 35 per cent. iron, and must be concentrated or beneficiated to find a market.

A more detailed description of the Michipicoten and Moose Mountain deposits will be found in the Appendix, where the known iron ore deposits of Ontario are listed and briefly described.

CHAPTER IV

PROSPECTING AND MINING METHODS

The reports and accompanying maps based on the preliminary geological work and published by the Ontario Department of Mines and the Geological Survey at Ottawa, contain a wealth of detailed information and form a practical guide for any prospector going out to look for an iron ore deposit. The report entitled "Iron Ore Occurrences in Canada," with reference maps, published by the Mines Branch in Ottawa in 1917, is deserving of special mention.

Structural geology, and its influence on deposition and secondary enrichment of iron ore deposits, has been referred to in Chapter III.

No work of this kind could be expected to outline with any degree of satisfaction, just how a prospector should go about the discovery of iron ore, or any other mineral. The successful prospector must have a natural instinct suiting him for that work; and perhaps no two of the successful prospectors would undertake the same investigation in the same way. Suffice it to say that the general order is to locate, with the assistance of the geological maps furnished by the Government, the area that gives promise of containing the mineral sought for—in this case, iron ore. Arriving on the ground, the prospector will endeavour (where the formation is exposed) to ascertain and to trace the contact, and having located a deposit of iron ore, to determine in a general way whether or not it is large enough to justify surface trenching, or other forms of intensive prospecting. If, in the opinion of the prospector, it is worthy of such consideration, he will as a rule run cross-trenches at favourable points across the strike of the ore body, so that he may determine and prove to anyone interested its approximate length and width. Channel samples in these cross-trenches will be taken where the ore is exposed. This sampling may show ore of a commercial grade, or at least of a nature and quality that suggests the possibility of economic beneficiation. Its boundaries, as far as possible, must next be determined. This preliminary data may often be best obtained by the magnetic survey. The magnetic method of prospecting for iron ore has been successfully used in locating and delimiting magnetic deposits. A detailed description of the method, as presented by Prof. A. L. Parsons, will be found in the Appendix to this report.

Having determined, then, that over a large area the ore is of commercial grade, or that in case it falls below that classification the ore body appears to be of a size and quality that might justify the erection of a beneficiation plant and its development on a large scale, we come to the preliminary stage of investigation as to actual or positive tonnage.

Diamond Drilling and Development

In the soft ore bodies on the American side in the Lake Superior district, different kinds of drills are used to obtain the sample well below the surface, but so far as our present knowledge goes, Ontario deposits can best be prospected with a diamond drill. The usual practice, having determined the strike and dip of the contact, is to put a series of holes, 50 to 100 feet apart, in a straight

line at right angles to the margin of the ore deposit, letting one hole in each line go some distance below the iron formation, to make sure that the ore deposit has been bottomed. Very careful and accurate samples are taken from the sludge and also from the ore recovered, and all the information obtained is carefully tabulated for each hole, and a cross-section of the ore body plotted. With a series of these cross-sections the available tonnage of different grades can be fairly accurately estimated, and generally sufficient information can be obtained to settle definitely whether or not the ore body warrants further development.

If the tonnage and grade appear satisfactory from the information obtained, the next step is to locate a shaft, generally on the footwall side of a deposit, and on different levels to run cross-cuts from the shaft to the farther margin of the iron ore. This not only serves to check, in a most practical way, the results obtained by diamond drilling, but it gives the operator some opportunity to determine the method of mining that may best be applied, and considerable data of use in determining approximately the cost of production.

Methods of Mining Iron Ore

In the Lake Superior district, and by that we mean in this report the iron ore region on both sides of Lake Superior, irrespective of the international boundary, there are two distinct methods of mining, viz., *surface and underground.*

On the Mesabi range, where the ore is soft enough to be moved with a steam shovel, the practice within certain limits, is to remove completely by steam shovel the surface burden from the area to be mined, and then to take out the ore by the same method. There are so many advantages over the usual underground practice manifest in this method that it is used wherever there is not more than one yard of overburden to be removed for every ton of ore to be extracted, and where the vertical depth of the overburden does not exceed two feet of stripping to one foot of ore. There are, of course, exceptions to this rule, as, for example, when the nature of the overburden makes it difficult to move; there is also a limit to depth when taken in conjunction with transportation problems. Generally speaking, it may be said that all other things being favourable, surface stripping may be followed to a depth of 150 feet and the ore removed from depths beyond that limit. This system of open-cut mining has been described at great length and its advantages and disadvantages set out in detail in so many technical papers that further description of it in this report would, perhaps, be out of place.

Underground mining falls into three divisions:—

(1) The top slicing and caving method.

(2) The milling, or open-cut glory-hole method.

(3) The ordinary shrinkage stope practice.

In the top slicing and caving method, the extraction of the ore body commences at the top of the deposit and below the overburden. The back is supported by timber. As the ore is broken it is dropped through chutes to the haulage levels, and as the process continues downward, the overburden and timber supports are allowed to cave and settle. Where the ore is soft and easily caved, and especially where it varies radically as to grade, there are many

advantages in the top slicing method: The extraction of the ore body is fairly complete, since little is left in the way of pillars; selective mining is made possible; and different grades from different parts of the mine may be blended in such a way as to meet the consumer's requirements. However, the number of working places is limited. Pumping must be continued at all times, irrespective of the rate of production, and if any sudden demand arises for ore, the method, unlike that of the open pit, does not lend itself to sudden expansion.

The milling or glory-hole method is a combination of open-pit and underground mining. The shaft is put down in a suitable location, a cross-cut is driven into the centre of the ore body, and a raise is carried through to the surface. Stoping operations start at the surface, and the ore is broken into the raise, which from now on functions as an ore chute. As operations continue, the surface is naturally lowered and takes the form of a great saucer or open pit. This is undoubtedly a cheap method of mining hard rock, but there are certain serious disadvantages. In the first place, all the water falling upon the open pit runs directly into the underground workings and must be pumped. During the severe weather in the winter time, the miners often suffer from extreme discomfort, and water lines cannot be kept open. If the ore body has any perceptible dip, there has to be faced the difficulty of keeping the hanging wall scaled to a point where it will be safe for the men working underneath; beyond a certain depth it will probably be found necessary to break down a considerable portion of the overhang, thus diluting the ore and lowering the grade.

The shrinkage stope method of mining is quite familiar to those with a knowledge of the mining methods employed in this province. From the standpoint of safety it undoubtedly has great advantages over all methods other than the open-pit or surface method. However, the costs of breaking the ore and extracting it, are comparatively high as compared with any of the other methods.

Any or all of these methods may, and we hope some day will, be applicable to the working of Ontario deposits of iron ore, but so far as the present known deposits are concerned, the two last described processes will usually prevail. Costs will probably not be in any case much less than $1.00 per ton delivered at the collar of the shaft and in the majority of instances will probably exceed this estimate.

The one dollar estimate covers, of course, only the cost of underground operations. To ascertain cost of production other items must be added, such as taxes, depletion, depreciation, overhead expense, selling commissions, insurance, etc.

Actual figures covering cost of production cannot be obtained for publication, but for a certain period we can give some comparative figures.

On the following page will be found approximate costs of production of iron ores from underground workings at mines on the Marquette, Gogebic, Menominee, and Mesabi ranges, and from surface workings at mines on the Mesabi, Cuyuna, and Gogebic ranges.

The costs at the underground mines, rather than those of surface operations, are of importance in making comparisons with iron mines in Ontario. The [illegible] of steam shovels for mining iron ore in Ontario is not likely to be found possible at any of the known deposits.

Mesabi open-pit ore has the lowest cost of production, and if we assume, for the sake of comparison, that this particular ore costs $2.20 per ton to produce at the mine, we can lay down the following statement:—

COMPARATIVE COSTS OF PRODUCTION OF IRON ORES

Ores		Cost of production per ton	Average cost of production per ton
Open pit	Mesabi	$2.20	$2.40
	Cuyuna and Gogebic	2.50	
Underground mines	Marquette	3.80	3.75
	Gogebic	4.20	
	Menominee	3.50	
	Mesabi	3.50	
All Lake Superior iron mines		....	3.25
Ontario ore (beneficiated), about		....	5.20

CHAPTER V

CONCENTRATION OF LOW-GRADE MAGNETIC IRON ORES

The low-grade ores that can be beneficiated are of three general types. These are siderite, hematite, and magnetite.

Siderite is an iron carbonate containing, when pure, 62 per cent. of iron oxide and 38 per cent. of carbon dioxide. This ore is beneficiated by heating it and driving off the carbon dioxide, as described in the chapter on sintering.

Low-grade hematite ores consist of a mixture of hematite and quartz or silicates. There are two processes of beneficiation suited to such ores. Where the hematite is in hard aggregates and the waste is soft or friable, a separation can be effected by log-washing. This is practised on a large scale in Minnesota. The log-washer consists of two parts, an inclined trough in which rotates a rough spiral conveyor (the log). The arms on the log disintegrate the friable rock and gradually convey the more solid material to the upper end, while the wash water washes away the waste at the lower end. The Mines Experiment Station at Minneapolis has developed the process of treating low-grade hematite ores to a magnetic roast whereby the hematite is converted into magnetite which can be separated by magnetic separators.

The third type is a mixture of magnetite and waste minerals, of which large bodies have been found in Ontario.

On this continent it does not pay at the present to ship to the smelters ore containing much less than 50 per cent. iron. The smelters do not want it. It costs too much in fuel and flux to get rid of the waste material. In Ontario there are large bodies of iron ore, containing from 30 per cent. to 37 per cent. of iron, which consist of a mixture of particles of magnetite and waste minerals. This waste consists largely of quartz and silicates, some pyrite (iron sulphide), and, in much smaller quantity, some phosphorus-bearing minerals. All these may be separated by crushing and grinding the rock. The degree of fineness required depends upon the size of the individual particles or crystals.

In the Mineville district, in New York state, crushing the rock so that it will pass through a five-mesh sieve, that is, a wire sieve with five holes to the lineal inch, is sufficient to free practically all the magnetite. Crushing it to pass through holes one inch in diameter results in freeing many pieces of practically pure magnetite of this size. This ore is easily concentrated by magnetic separators. Most of the magnetite ore discovered in Ontario is of much finer grain and requires very fine grinding to separate the magnetic particles from attached waste.

For the separation of the magnetite from the waste, after sufficient fine grinding, there are various types of apparatus, generally known as magnetic separators. They are all based on the attracting and holding power of electro-

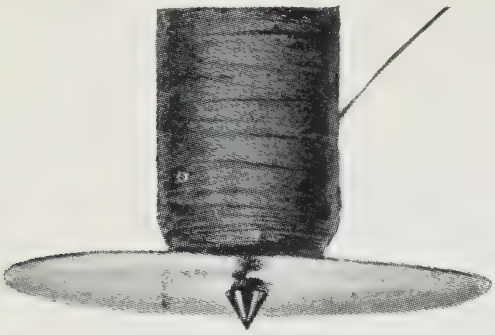

Fig. 1—High-power electromagnet.

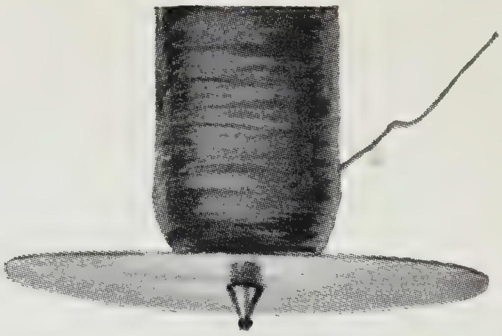

Fig. 2—High-power electromagnet with hematite.

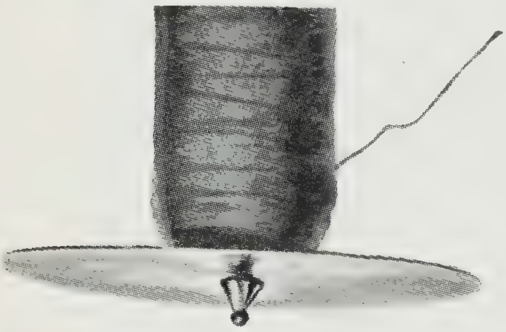

Fig. 3—High-power electromagnet with siderite.

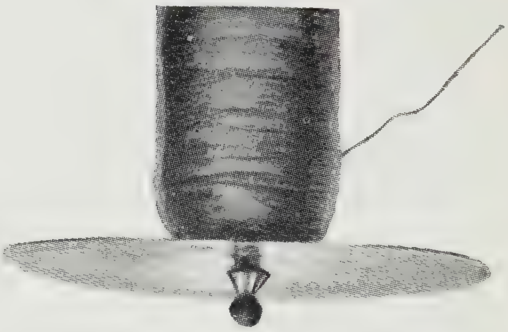

Fig. 4—High-power electromagnet with pyrrhotite.

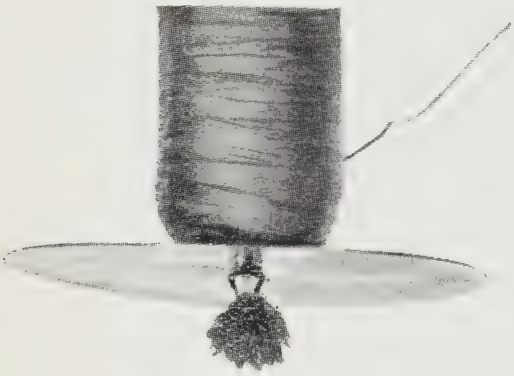

Fig. 5—Highpower electromagnet with ilmenite.

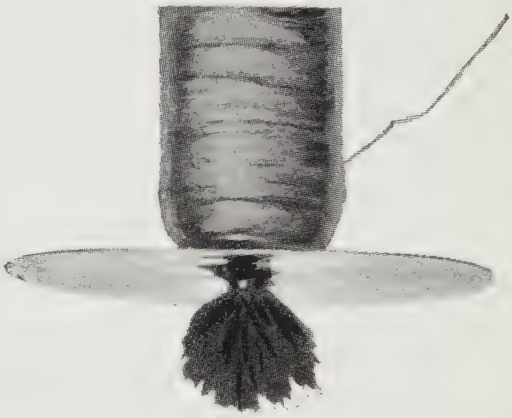

Fig. 6—High-power electromagnet with franklinite.

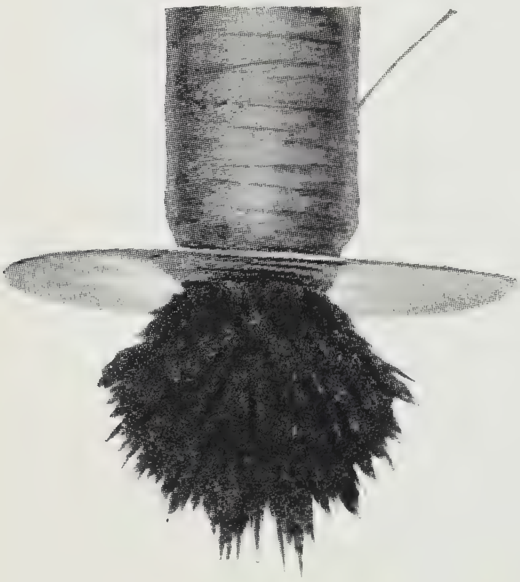

Fig. 7—High-power electromagnet with magnetite.

Fig. 8—High-power electromagnet with iron filings.

magnets. This power, as applied to various minerals, is well illustrated in the accompanying figures.

These illustrations are taken by permission from the bulletin of the University of Minnesota, entitled "Magnetic Concentration of Iron Ore," by Edward W. Davis, Superintendent of the Minnesota School of Mines Experiment Station.

Upwards of one thousand patents have been issued through the U.S. Patent Office, in connection with magnetic separators. A few simple types have survived. Fig. 9 shows a Ball-Norton belt separator as used at Mineville. The ore is fed to the upper side of the lower belt. The magnetic particles are lifted from this belt to the under side of the upper belt by the electro-magnets. The poles of these magnets alternate in sign. The loops of magnetic particles are broken and re-form as they pass from pole to pole, thus permitting the falling away of any non-magnetic material that may have become entangled. This separator works best on ore not coarser than three mesh, nor finer than one hundred mesh, but its capacity with the finer sizes becomes very low.

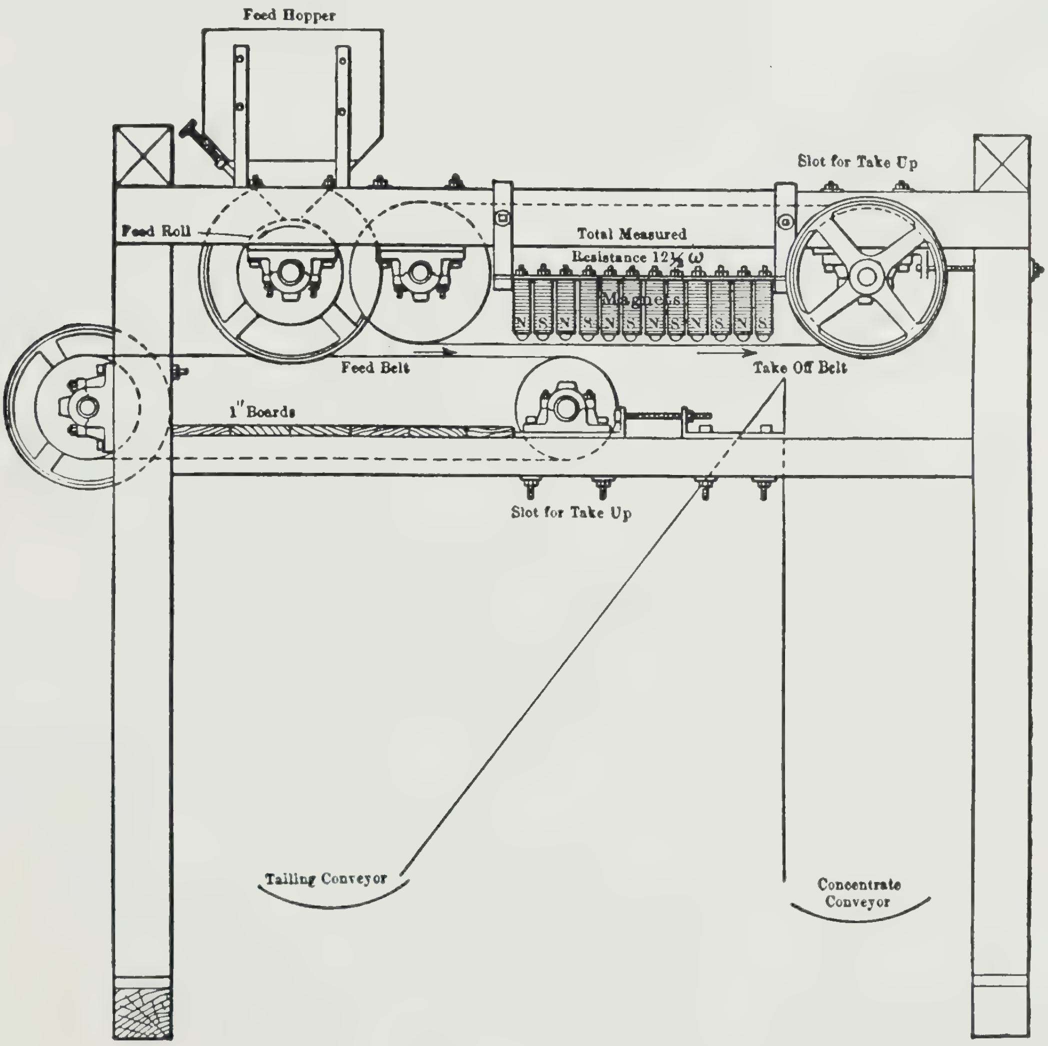

Fig. 9—Ball-Norton belt separator.

For coarser sizes a simple magnetic drum and short conveyor belt are used, as illustrated in Fig. 10. The magnets may be fixed and the hollow drum may revolve about them, or they may be an integral part of the drum and revolve

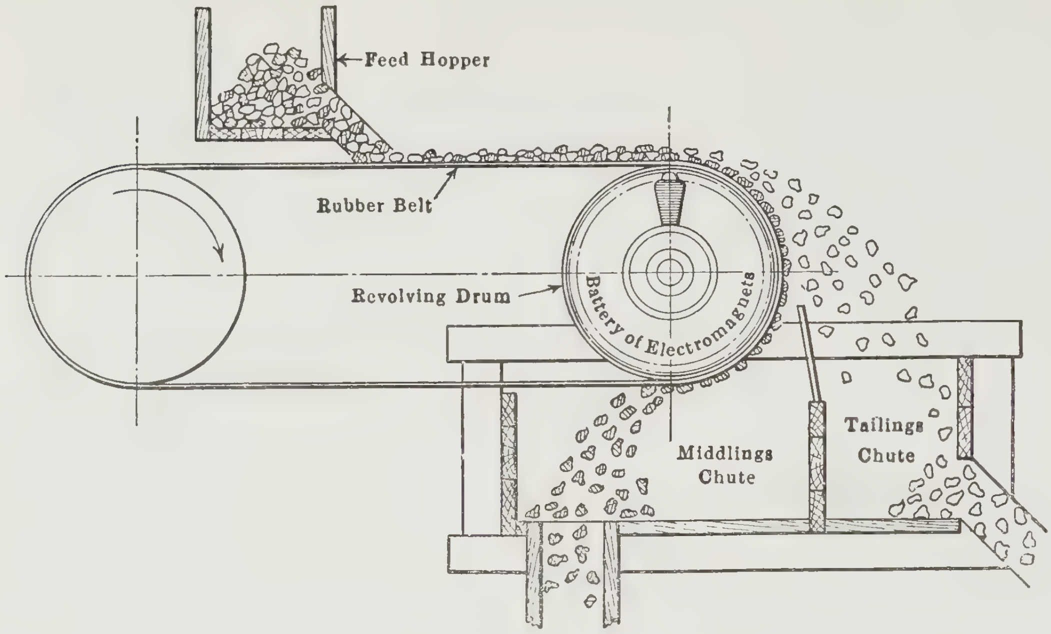

Fig. 10—Ball-Norton pulley machine.

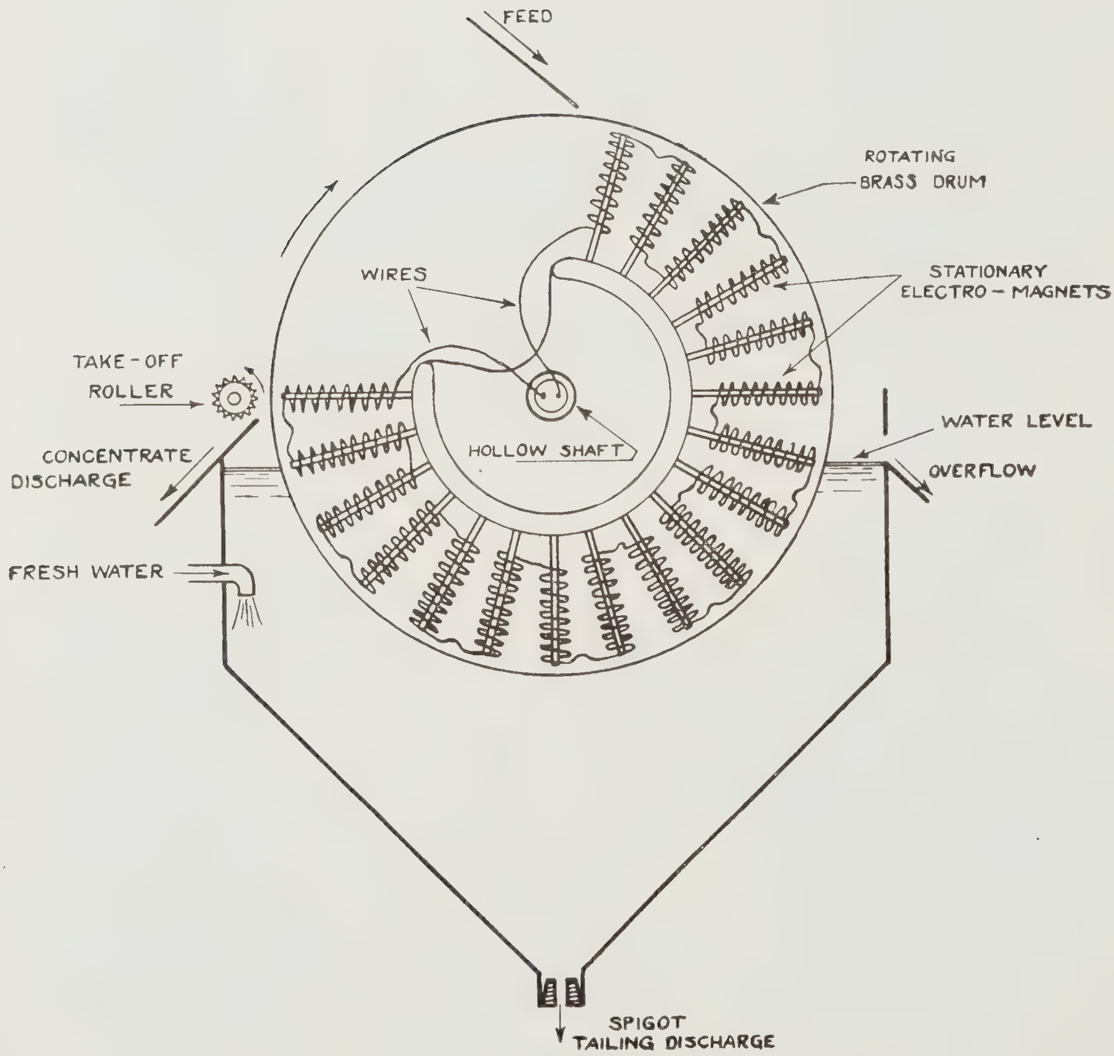

Fig. 11—Diagrammatic drawing of wet cobber.

with it. This type of machine is also called a magnetic cobber. It has been used for finer material, both dry and wet, but is not recommended for such work.

For wet material between three mesh and one hundred mesh, a successful type of machine is shown in Fig. 11. For material finer than one hundred mesh,

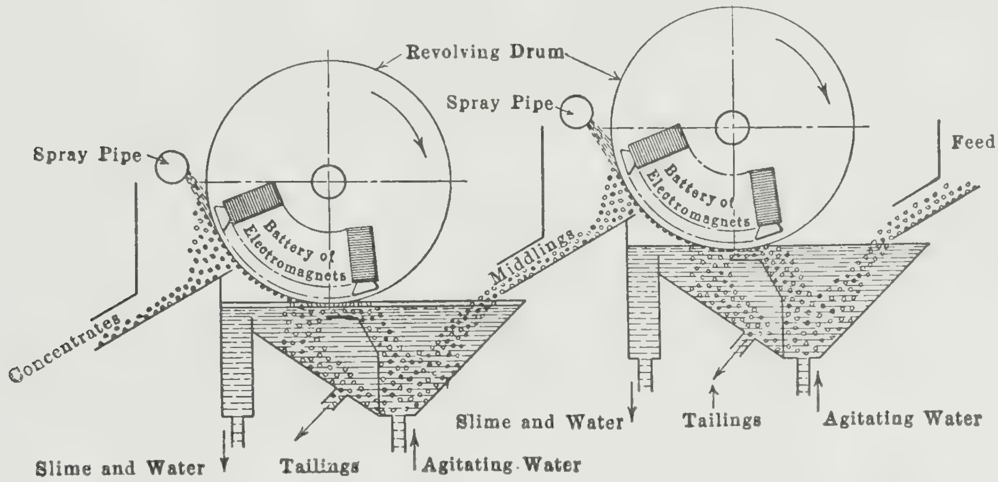

Fig. 12—Gröndal wet separator.

the Gröndal separator (see Fig. 12) is much used in Norway and has been successfully used at the Moose Mountain plant at Sellwood, Ontario.

At the Minnesota School of Mines Experiment Station, E. W. Davis has developed an entirely new type of separator for very fine material, known as the "magnetic log-washer." Mr. Davis, in his description of this in the bulletin

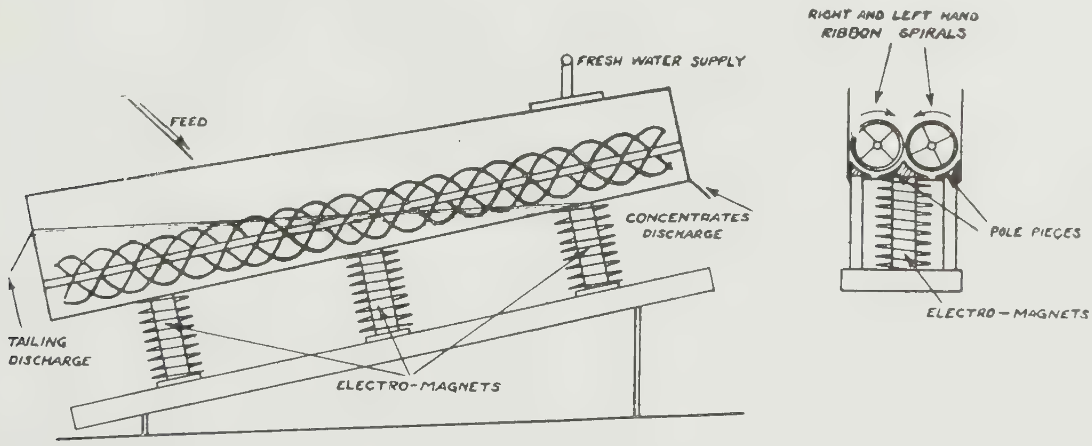

Fig. 13—Diagrammatic drawing of magnetic log-washer (Davis).

referred to, says: "As the name implies, this machine is similar to the log-washers now in common use in the Lake Superior district. Magnets have been applied to the lower side of the machine in such a manner as to place the whole bottom of the trough in a magnetic field." Fig. 13 is a diagrammatic drawing of this machine. From this drawing, its similarity to the log-washers may be

easily recognized. This machine is adapted to the concentration of finely ground ores, and the finer the ore is crushed the better the machine operates. The ore, in either a dry or wet state, is fed to the machine at the point indicated in the drawing and, after sinking into the water, at once enters the magnetic field. The magnetic particles, together with the entrained non-magnetic particles, are drawn to the bottom of the machine where they cling, not only to the magnets, but also to each other. As a result of the mass action, the screw

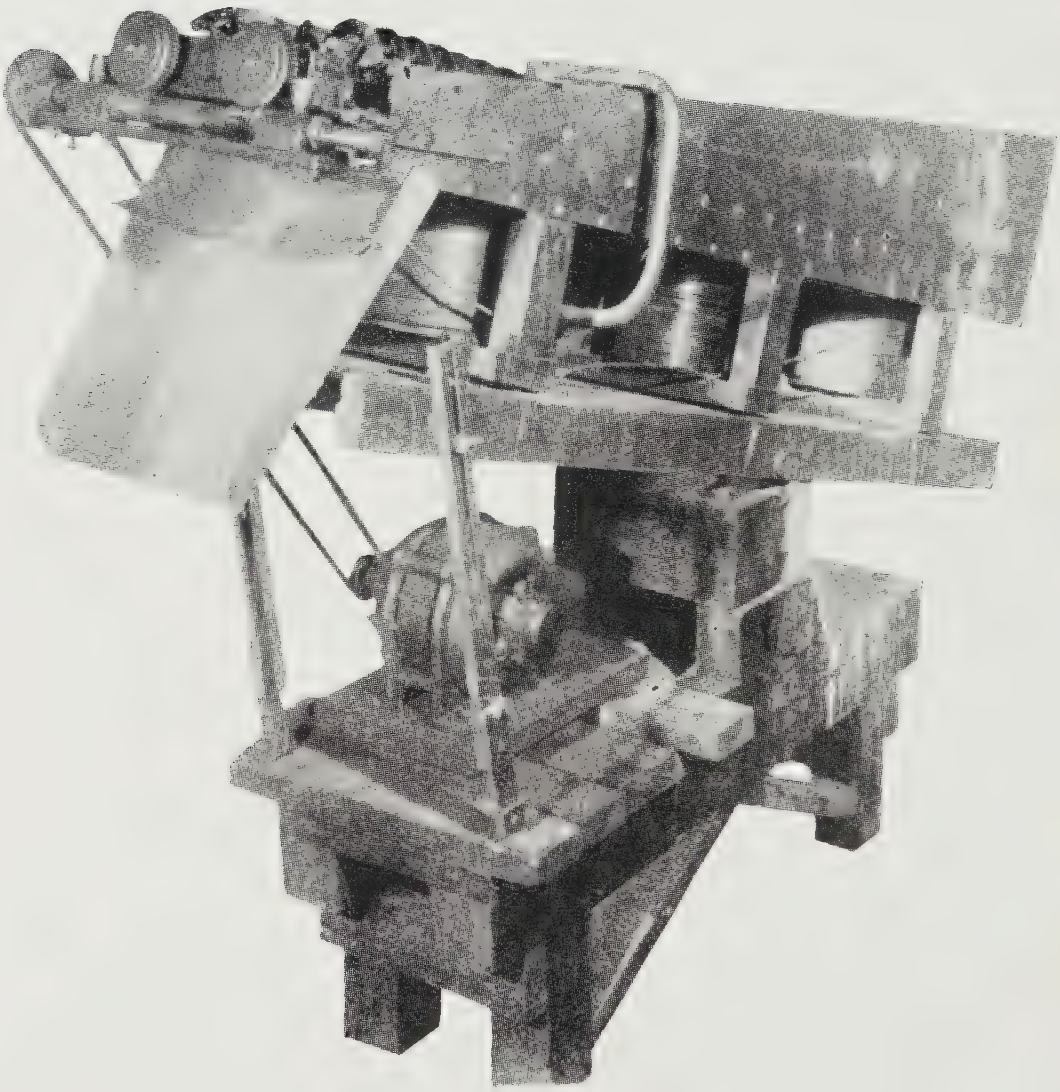

Fig. 14—Magnetic log-washer, 60-inch.

conveyor readily stirs and conveys the ore, while the wash water added at the upper end of the machine flows through the mass toward the overflow at the lower end, carrying away the non-magnetic particles as rapidly as they are liberated. High-grade concentrate is carried up the incline by the screw conveyor and is discharged from the upper end of the machine. Fig. 14 is from a photograph of a machine sixty inches long. The standard machines of this type at Babbitt are eighteen feet long and six feet wide and are equipped with four spiral conveyors.

The machine is remarkable for its simplicity and effectiveness, and also for the fact that the finer the feed is crushed the better it works. These are the machines from which was being produced, at the time of our visit, all the concentrate at the Babbitt plant.

The great difficulty in the operation of individual machines lies in the enmeshing, or entangling, of non-magnetic particles with the magnetite. When they are in the magnetic field, the particles of magnetite form themselves into chains and loops and entangle more or less waste particles with them. Davis developed his log-washer in such a manner that the magnetite is allowed to entrain the waste, which, while the mass is retained in the magnetic field, is then freed by mechanical agitation and the current of wash water.

None of the machines described are complicated in construction or difficult to operate. They will all make high-grade concentrate if fed with material which has been sufficiently crushed to liberate the magnetite from attached waste. Apparently the problem is a simple one, but this seeming simplicity has been the cause of many failures. It has caused inexperienced men to embark

Fig. 15—Magnetic log-washer, 18 feet long, Mesabi Iron Company.

on big plants without sufficient preliminary experiment. With the perfected magnetic log washer, the problem seems simply to obtain fine grinding. If the grinding is fine enough to liberate the smallest particles of magnetite, the log-washer will do the rest. If we disregard cost, this is the complete answer. But the solution of all concentration problems becomes the balancing of costs. The cost of fine grinding, both for plant and operation, increases very rapidly when we seek to get particles finer than one hundred mesh. Fine concentrate becomes difficult to handle and to sinter. All the magnetite ores in the Lake Superior region, including Ontario, contain some extremely small particles of magnetite. Unless the whole product is ground as fine as these minute particles, there will occur in the concentrate many particles made up of magnetite attached to waste (which often contains phosphorus). This pulls down the general grade of the concentrate. There are three solutions to this problem. The most obvious is to grind finer, but this runs up the cost. The second solution is to improve the machines and the operation so as to throw these mixed particles into a

separate product, middlings, in order that it may be necessary to regrind only these middlings. This means that the machines must distinguish between 30 per cent. and 50 per cent. iron content in the particles, or even between 40 per cent. and 50 per cent. The third solution lies in the fact that these finer particles are generally found in the poorer portions of the rock. The magnetite-bearing rock may show a general average content of 30 per cent. iron, but some parts of it may be nearly pure magnetite and other parts nearly all waste, while still other parts will show all the grades in between. If we crush the rock into one-inch fragments it will be possible to sort out individual pieces containing only 3, 6, or 10 per cent. of iron, and it will often, if not universally, be found that in this low-grade stuff there are finer particles of magnetite than in the richer stuff. The solution of the problem, then, is to discard this low-grade rock in the coarse sizes before grinding is commenced. In order to do this it is necessary so to operate the coarse separators, or cobbers, that they can throw out a tailing which will assay 6, 8, or 10 per cent. iron. This means that the machines should be able to distinguish between, say, an 8 per cent. iron content and a 12 per cent. Magnetic cobbers, previously illustrated, will do this fairly well, but there is room for improvement.

From this it will be apparent that the general problem is not simply the separation of magnetic from non-magnetic. It includes the separation of 6 per cent. ore from 10 per cent. ore and the separation of 60 per cent. particles from 40 per cent., or, better still perhaps, from 50 per cent. particles. The general problem, however, involves more than this. What is the grade of ore that must be eliminated in the early stages—is it 3, 6, 10, or 15 per cent.? The economical success of the plant may depend on the proper answer to this question. This entails a large amount of work by skilled men in a suitable laboratory under the direction of a man of experience. Even after this has been done in a thorough manner, there will be a period of adjustment, or tuning up, in the commercial plant. If the preliminary testing was not thoroughly done, this period may be an extremely expensive one and may involve a breaking strain on the finances, coming as it does at the time when a saleable output is expected. Other difficulties have arisen in the past with standard ore-dressing apparatus. Coarse crushers have failed on account of the hardness (or other crushing peculiarity) of the iron ore. Much trouble has been experienced with the classifiers in the closed circuit of the fine-grinding tube mills. This is the apparatus which separates the stuff which is sufficiently fine from the coarser material which must be returned to the tube mill for further grinding. Much trouble was experienced in these classifiers when a product was sent to them that had previously been over a magnetic separator. The magnetite had become permanently magnetized (polarized) and particle attached itself to particle, making classification practically impossible. The Minnesota School of Mines Experiment Station solved this difficulty with its demagnetizer. A diagrammatic drawing of a demagnetizer is shown in Fig. 16. It operates, on the same principle as the instrument for demagnetizing watches, by supplying an alternating electric current to the coil of wire which results in the production of an alternating magnetic field within the pipe. As the ore passes through the pipe it loses its residual magnetism because of the rapidly alternating magnetic field through which it passes.

Similar troubles have caused serious delays in the hands of experienced men at more than one plant, but the cause and remedies are being worked out, and in the future there will be reaped the benefit of this pioneer work.

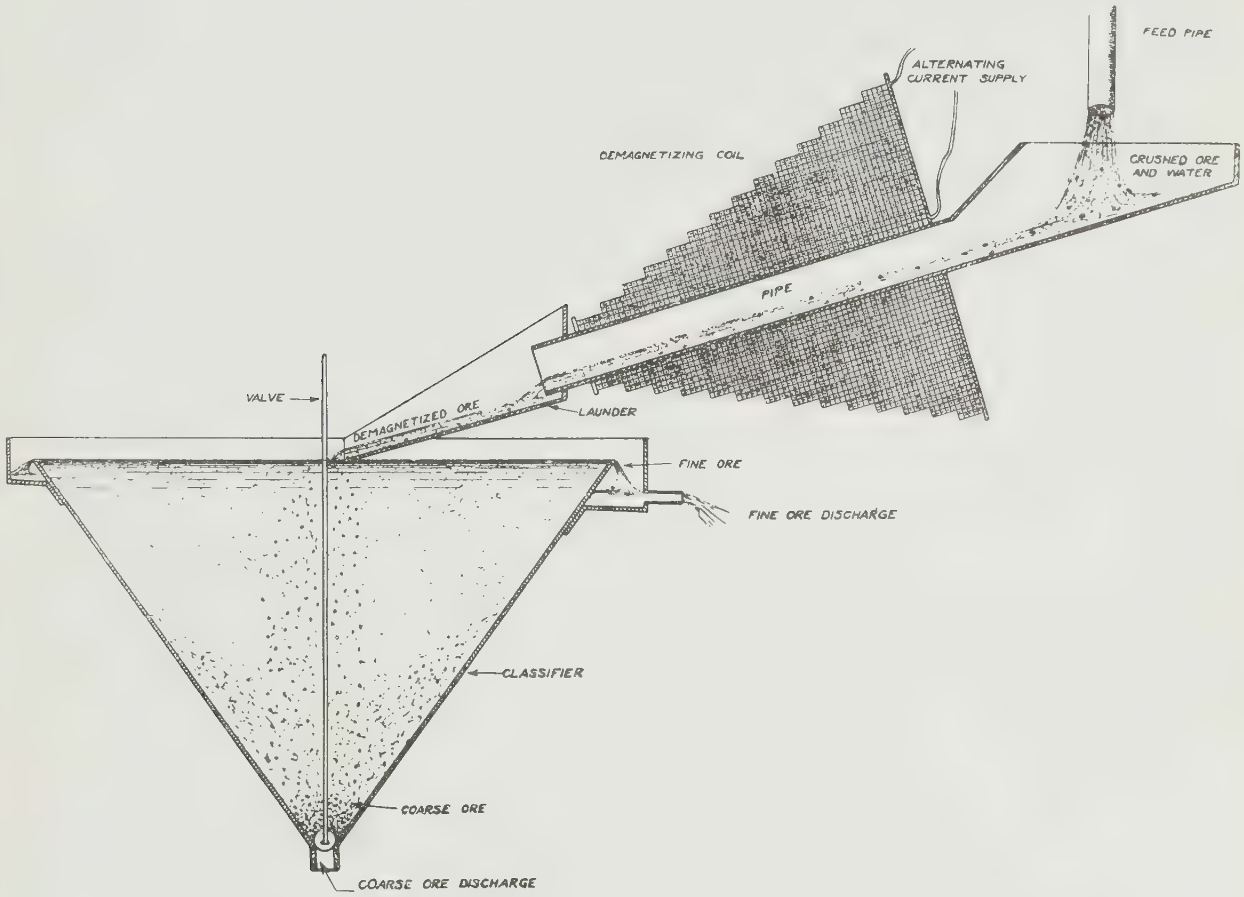

Fig. 16—Diagrammatic drawing of demagnetizer (Davis).

The way has been made clear for the production of a high-grade sinter from practically any ore containing magnetite. The lowest grade of ore that it will pay to treat depends upon economic conditions, but generally speaking, under the most favourable conditions, the ore should contain not less than 27 per cent. of iron in the form of magnetite. From this it is not difficult to obtain a sintered product containing 60 per cent. of iron, and low in phosphorus and sulphur. Technically, it is quite possible to make a product containing 70 per cent. of iron, but the economical grade will be somewhere between these two limits and will vary with different ores, different local conditions and market demand.

The presentation of valuable cost data in connection with the magnetic concentration of low-grade ore is extremely difficult. Conditions are so variable that only through detailed study of each particular problem can reliable figures be secured. It may be necessary to mine and crush nearly three tons of ore; cob, fine grind, and concentrate two tons of ore; dewater and agglomerate one ton of ore; stock-pile part of this and dispose of two tons of tailings for every ton of final product shipped. The cost of grinding, both for plant and for operation, increases very rapidly as it is necessary to grind finer. So it is necessary, before any complete estimates can be made, to know how much of the ore can be eliminated as waste in the coarser sizes, and how fine the balance must be ground in order to produce the necessary grade of concentrates.

Speaking generally, for large mills to crush from mine size to four mesh would cost from 10 cents to 20 cents per ton; from four mesh to minus 200 mesh, from 30 cents to 45 cents per ton. The other milling operations, that is magnetic separation and handling of products, will cost from 15 cents to 30 cents per ton of material treated.

In the same way, it is impossible to estimate the construction cost of a plant without knowing the local conditions, but it would be from \$2 to \$3 per ton of yearly capacity when the plant is operated three hundred days of twenty-four hours each per year. This does not include the power plant, or transportation facilities.

CHAPTER VI

PREPARATION OF CONCENTRATES FOR THE BLAST FURNACE, BRIQUETTING, NODULIZING, SINTERING, AND CALCINING

Ontario magnetites require concentration because they are low in iron, that is, they contain a large amount of rock matter, which is chiefly silica or quartz. This rock matter, or gangue, would be made into slag if such ores went direct to a blast furnace. In concentrating these magnetites, the rock matter is removed as tailing. The fact that it is cheaper to make a tailing than to make slag, is the economic reason for concentration.

To effect concentration, crushing and fine grinding are necessary in order that the magnetite particles may be separated from the rock particles. The result of this concentration is a product high in iron, but very finely divided. This finely divided material is unsuited for immediate smelting in a blast furnace for several reasons, the chief of which is that a very large proportion of it would be blown out of the furnace by the blast. It would require additional expense to recover this iron as flue dust. There is apparent, therefore, the need of changing the physical form of this fine concentrate. Methods for doing this may be classified as follows: (1) Briquetting, (2) Nodulizing, (3) Sintering.

Briquetting

Briquetting means, obviously, making into briquettes or cakes. This may be done with a binder, but such is seldom, if ever, used for iron ores. A briquette to be satisfactory must be able to stand handling and transportation without disintegration; it must be resistant to exposure in the open air; and it must be able to exist without crumbling in the upper part of a blast furnace. Few briquetting processes can meet these rather rigid requirements.

One of the best known processes for briquetting is the "Gröndal." This process had its inception in Norway and Sweden. The fine, moist ore is compressed into bricks, loaded on cars, and the cars are run into a furnace heated by coal, producer gas, or similar fuel. As they enter the furnace they reach gradually the hottest part, and on leaving they are gradually cooled. The high cost of fuel makes this process an expensive one in Ontario.

The only criticism of briquettes made by this process is that for the blast furnaces they are too large for the proper burdening of the furnace; also, they are too large for ferro-silicon furnaces.

Nodulizing

Nodulizing is an agglomerating process carried out in a rotating, cylindrical kiln about 125 feet long and 8 feet in diameter. The kiln, which inclines slightly, is fired with pulverized coal at the lower end. The fine ore is charged at the upper end and travels slowly toward the firing end, getting hotter as it proceeds. The high temperature makes the particles stick together, or agglomerate into balls or nodules, which are discharged continuously at the lower end of the kiln. The kiln is similar to those used in the production of cement. The plant is expensive to install and the fuel consumption is excessively high.

Sintering

There has been a very great improvement in the last few years in the capacity of the machines used, and a consequent reduction in costs of operation. There are two different types of sintering machines applicable to iron ores. Both machines use the same principle and they differ only in the type of apparatus employed. The principle involved may be illustrated in this way: Fine ore is mixed with 6 to 8 per cent. of its weight of finely pulverized coal, or similar fuel, moistened and spread on a grate in a layer about 8 inches thick; air is drawn by a fan through this grate and the layer of mix which it bears; the charge is ignited by a hot flame; after ignition is made the combustion of the small amount of fuel proceeds downwards through the cake. A high temperature is attained momentarily as this combustion proceeds, and this temperature is sufficient to make the whole mass into a coherent, spongy cake, known as a sinter.

The process had its first application in the sintering of fine lead ores. In the lead, copper, and zinc industries, its details have been worked out and its success demonstrated. It is only in comparatively recent years that this process has had much application in treating fine iron ores and iron blast furnace flue dust; but so great has been the success achieved that this process is almost exclusively used in modern installations.

The Greenawalt pan is intermittent in its action. The fine ore to be sintered is mixed with the necessary fine coal or coke in a mixing cylinder, where it is properly moistened. The cylinder discharges the ore into a bin from which it is transferred in a car to the pan. The levelled charge is then ignited by means of the ignition hood which is moved over the pan, covering it completely. This hood is similar in some respects to the hood used in connection with repair work on our asphalt paved streets. After ignition the charge burns with the down draft, the temperature produced by the burning coal being sufficient to partially fuse the whole mass into what is called a sinter. The structure of this material is very similar to that of coke. The burning time is about twenty-five minutes. When the sintering is finished the pan is rotated on its trunions; the charge is dumped over a grizzly; the fines are returned; and the coarse goes directly to railroad cars. The modern Greenawalt sintering pan is 24 feet by 10 feet in size, with a cast iron grate bottom. The pan rests on the wind box from which the air is exhausted by a fan at the rate of about 20,000 cubic feet of air per minute.

The other machine for sintering is the Dwight and Lloyd machine. In this machine the grates, or palettes as they are called, move over a wind box where their charge is ignited, and their rate of travel is so regulated that sintering is completed by the time thay have reached the end of the wind box. The Dwight and Lloyd machine is therefore continuous.

The modern Dwight and Lloyd machine is about 64 feet long and 42 inches wide. It consists of some sixty odd trays, about 24 inches by 42 inches, with cast iron grates and two end walls about 9 inches high. At one end these trays receive the properly mixed and wetted charge which is made up of the fine ore and fine coal or coke, the surface being levelled as they are filled. As they

move on the wind box they pass under the ignition furnace which burns oil or gas, and as the trays continue their movement over the wind box, combustion of the coal in the mix proceeds and a sufficient temperature is attained to make a strongly coherent cake or sinter. The trays automatically dump their charge. The amount of coal or coke required in the mix varies with the material, ranging from 3 per cent. to as much as 8 per cent. Sulphur when present in the ore reduces the amount of fuel necessary for sintering, as its oxidation and removal furnishes considerable heat.

The Dwight and Lloyd machine possesses marked advantage over the intermittent Greenawalt pan, but the use of the large pans in the more recent Greenawalt installations has put the two processes on a basis of equality, so that opinions are comparatively evenly divided as to the relative merits of the two machines for producing sinter. Both types of operations have their champions, each claiming some advantages over the other, but they are similar in principle and produce a similar product, so that the one which will show the lowest operating cost will be the best for any particular case.

In addition to changing the physical form of the fine ores, the sintering process is an excellent desulphurizer. The passage of the volume of air through she cake during the process of sintering gives opportunity for the oxidization and removal of sulphur in the charge. Ores containing from 3 to 5 per cent. of sulphur are successfully reduced to from 0.1 to 0.2 per cent. sulphur.

At the E. & G. Brooke Company's plant at Birdsboro, Pa., a Dwight and Lloyd machine is sintering and desulphurizing their French Creek magnetite. This ore is a magnetite containing 55 per cent. iron and averaging 3 per cent. sulphur. The ore is crushed to pass a ring three-eighths of an inch in diameter. Sinter containing from 0.1 to 0.2 per cent. sulphur is made, using from 3 to 3.5 per cent. of fine anthracite as fuel. Ignition is made with iron blast furnace gas. The average daily tonnage on a 57-foot machine is 400 tons per day. The cost of sintering is about 90 cents per ton, including the royalty of 15 cents per ton. Lower costs than this have been made. At times the sulphur content in the ore seems considerably above 3 per cent., but a uniformly low sulphur sinter is made.

At the present time, either the Dwight and Lloyd machine or the Greenawalt pan offers the cheapest and most effective means of putting fine ores in condition for blast furnace use.

The new plant of the Mesabi Ore Company, at Babbitt, Minn., employs Dwight and Lloyd machines.

In the Eastern States the magnetite concentrates are sintered either with Dwight and Lloyd machines or Greenawalt pans. The largest installation (2,000 tons per day) at Lebanon, Pa., uses Greenawalt pans.

These machines are not fool proof, and the problem of making a good sinter and a high tonnage on either has to be worked out carefully for each individual case. It is essential that the amount of carbonaceous fuel needed, be in a finely divided state for rapid burning, and that it be uniformly mixed with the material to be sintered.

Inferior fuels, such as coke breeze, or possibly even finely divided peat, may be used, although the last-mentioned has not been used in this country.

Treatment of Siderite

Siderite, sometimes called ironstone, is a carbonate of iron, as limestone is a carbonate of lime. Ontario has important deposits of siderite. Of these the best known are the Helen and the Magpie mines. Because of the high carbon-dioxide content of these ores, the iron content is low.[1]

Iron ore going into a blast furnace contains, in addition to the iron, the oxygen with which the iron is combined, and the gangue, or rock matter, that is present in the ore. To do the smelting, coke is added and burned to CO at the tuyères by the blast of air supplied. The top gases contain the carbon in the form of the two oxides of carbon: carbon monoxide CO, carbon dioxide CO_2. For the reduction of the iron a certain relationship between the quantity of carbon monoxide and carbon dioxide must exist. If siderite, containing as it does a high percentage of CO_2, were charged directly into a blast furnace, to maintain this relationship or equilibrium would require the burning to CO of much more coke in the blast furnace, so much more that the removal of the CO_2 from the siderite before it is charged into the furnace is an economic necessity. This is, briefly, the reason why calcining of siderite ores is necessary.

Crushed siderite ore may be calcined and sintered in one operation, either on the Dwight and Lloyd machine or on the Greenawalt pan. The fuel consumption for this would be little, if any, higher than for sintering, say, magnetite concentrates. The reason for this is that the equation representing calcining of iron carbonate to Fe_3O_4 is almost thermally balanced. If the sinter contained much Fe_2O_3 it would mean that the reaction had really given out heat. The equation of the reaction may be written thus: $3\ FeCO_3+O=Fe_3O_4+3\ CO_2$. The heat of formation of $FeCO_3$ is 187,000, so that we have on the left hand side of the equation three times this quantity of heat, or 563,400. On the right hand side we have the heat of formation of magnetite 270,800, and three times the heat of formation of CO_2, 291,600, making a total of 562,400. The difference between these two quantities is 1,000 calories, or 6 calories per pound of iron and 4.3 calories per pound of magnetite sinter produced. As a pound of average coal may contain 7,000 calories, this would be equivalent to less than one-tenth of one per cent. of coal to sinter produced. To show the difference between calcining siderite and calcining limestone, a similar calculation might be made for limestone, and there will be found to be required 805 calories per pound of burned lime, which is equivalent to about 11.5 per cent. of fuel, which would be the theoretical requirement.

At the time the rotary kilns were installed at the Magpie, coal was cheap, and the sintering process had not reached its present state of development, so that there probably was, at that time, little to choose between the two processes.

These ores contain also considerable sulphur, and in their preparation for the blast furnace it is necessary to reduce this sulphur to permissible limits. To oxidize sulphur, more air has to be admitted into the kiln.

During the operation of the Magpie mine over a million tons of ore have been so treated.

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[1]For average analyses of ores of the Helen and the Magpie mines, see Appendix, pages 158 and 160.

In later years the cost of this operation has been greatly increased, due to the increased price of coal.

The Greenawalt pan, or the Dwight and Lloyd machine, will perform both of these operations, that is desulphurizing and calcining, as successfully as will the rotary kilns.

Sintering Tests in 1914

In 1914, 6,000 tons of Magpie ore were sintered on Greenawalt pans, according to reports of the Algoma Steel Company. The work extended over a period of about seven months and was thoroughly successful in every respect. All conditions, both of summer and winter, were met. The average on about 4,000 tons of sinter ran 0.23 per cent. sulphur, and an expenditure of 120 pounds of coke breeze per ton of product was required.

Five hundred tons of Helen ore were run over a Greenawalt pan, producing a sinter containing 0.146 per cent. sulphur and 55 per cent. iron. The report shows that the Helen mine ore makes a particularly good sinter, being almost 100 per cent. product, and there is no question that the Greenawalt is a thoroughly practical process for treating Helen Mine siderite.

Subsequent Tests on Helen Siderite Ore

Tests were subsequently made on a Dwight and Lloyd machine at the American Steel and Wire Company's plant in Cleveland, Ohio, and at the Toledo Furnace Company, Toledo, Ohio.

Three cars of Helen siderite were used in the test at Cleveland. Their summary of the result of the test at Cleveland is as follows:—

> These tests show that the Dwight and Lloyd sintering machine, as installed at the Central Furnace Plant of the American Steel and Wire Company, will reduce sulphur in Helen siderite to about 0.2 per cent. and that a very large tonnage is possible, that is from 300 to 350 tons per 24 hours, and that likely much more if everything was properly adjusted. However, we could not get the ore to come uniformly good, which compels us to try the ore on the machine at Toledo, where better mixing facilities are to be had, as the mixing is undoubtedly the cause of the trouble.

Two cars of Helen ore were used in the test at Toledo. The analysis of the finished product from this run is as follows:—

	Per cent.
Iron	55.66
Sulphur	0.18

This test absolutely demonstrated that at least 175 tons of first class material could be made per day of 24 hours.

The screen analysis of the material shipped for these tests was given as follows:—

		Per cent.
On	1 inch	2.5
	3/8 "	6.7
	1/4 "	32.3
	1/8 "	30.5
Through	1/8 "	28.0

This, apparently, shows crushing to approximately 1 inch size.

The improvement in the art of sintering iron ores and the increase in the capacity of the machine used make the sintering process more economical than the rotary kiln process. The saving in the cost of treatment of ore by this process may be sufficient to permit profitable operation where treatment by the kiln process would not. The cost of fuel is an important consideration in comparing the processes, and the superiority of sintering is now more marked than it was when coal was cheap.

CHAPTER VII

DESCRIPTION OF BENEFICIATION PLANTS AT BABBITT, MAGPIE, MOOSE MOUNTAIN, TRENTON, AND ATIKOKAN

Babbitt Plant

The most ambitious attempt ever made to beneficiate low-grade magnetic iron ores on this continent is undoubtedly that of the Mesabi Iron Company, on their Babbitt property in Minnesota.

Here, by lease and purchase, they have secured control of approximately fifteen miles of the eastern extension of the Mesabi Iron range. The ore body is so well exposed that surface stripping is almost unnecessary, and the results of development work indicate that the ore body is uniform in quality, with a natural magnetic iron content of not less than 26 per cent.

Without going into particulars, it is immediately apparent that their ore reserves are, to say the least, ample.

This deposit has been known since the early days, but with the discovery of the immense high-grade hematite deposits farther west on the same range, the so-called taconites of the eastern end were entirely ignored.

In the meantime, great progress has been made in the commercial exploitation of the low-grade copper ores in the western part of the United States. The success attending the efforts of those responsible for these new low-cost methods was largely dependent upon the magnitude of the ore deposit which permitted the installing of the most economic equipment and the mechanical handling of huge tonnages, at minimum cost.

Among the names of those standing out prominently as sponsors to this new departure in mining and milling, are Chas. Hayden and Daniel C. Jackling, the former identified with the financial end, and the latter with the operating and technical end. But these men were not content to rest on the success of one adventure, great as it was. They are essentially pioneers in the mining industry, and through a series of circumstances they conceived the possibility of applying the same process to the low-grade iron deposits, producing a superior product for the blast furnace that would compete commercially with even the high-grade natural deposits of the Western Mesabi range.

They knew from experience what could be done in handling profitably the low-grade copper ores. They thought the same process could be successfully applied to low-grade iron ores. Could it be done? There was only one way to find out, and capital was necessary.

In 1915, the Mesabi Syndicate was organized to investigate the whole question. Within a short time engineers were on the field and technical experts, in co-operation with the staff of the State Experimental Station at Minneapolis, were investigating the process of magnetic separation. Old types of machinery were redesigned, and the Davis log-washing magnetic concentrator was evolved. The preliminary information thus obtained, coupled with standard design and practice as in use in the large tonnage copper plants of the west, formed the basis of design for an experimental or pilot mill of 100-ton capacity per day at Duluth.

The mill was erected and crude material was brought down from the Babbitt property. Different machines were tested in a practical way, and results were charted with minute care. Different combinations were given practical tests, and this work continued in a most efficient manner until final plans were decided upon in 1919.

This preliminary experimental work had cost approximately three-quarters of a million dollars, and the practical application of the information had yet to be provided for.

In 1919, the Mesabi Iron Company was incorporated for this purpose, with the following directorate: Charles Hayden, Chairman of the Board; Daniel C. Jackling, President; John D. Ryan, W. E. Corey, Percy A. Rockfeller, C. M. McNeil, Sherwood Aldrick, W. Hinkle Smith, Alva C. Dinkie, Seeley W. Mudd, Horace V. Winchell, John R. Dillan, W. G. Swart, J. Carson Agnew.

Final plans provided for quarry, transportation, and primary crushing capacity up to 10,000 tons per twenty-four hours. Beyond this point the plant is designed on a unit basis, and the operation may be generally described as follows.

Mining

About a mile from the mill, the quarrying of the taconite has been commenced by taking out a cut approximately thirty feet deep and laying standard grade track for steam shovels and cars. On the bank, motor-driven cyclone churn drills operate and drill a 6-inch hole to a depth of thirty feet, at a rate of about one foot per hour. The holes are spaced at fifteen-foot intervals along the face of the cut. They are loaded with 60 per cent. dynamite and shot in series. With a small amount of block holing, the blasted material can be directly loaded by steam shovel into cars and transported as required to the crushing plant.

The rock is a banded magnetite.

Coarse Crushing Plant

The ore is dumped from hopper cars directly into a bin feeding an 8 by 31-foot pan conveyor, which in turn feeds it to a 48 by 72-inch jaw crusher with a capacity of 900 tons per hour from quarry size down to about 10 inches.

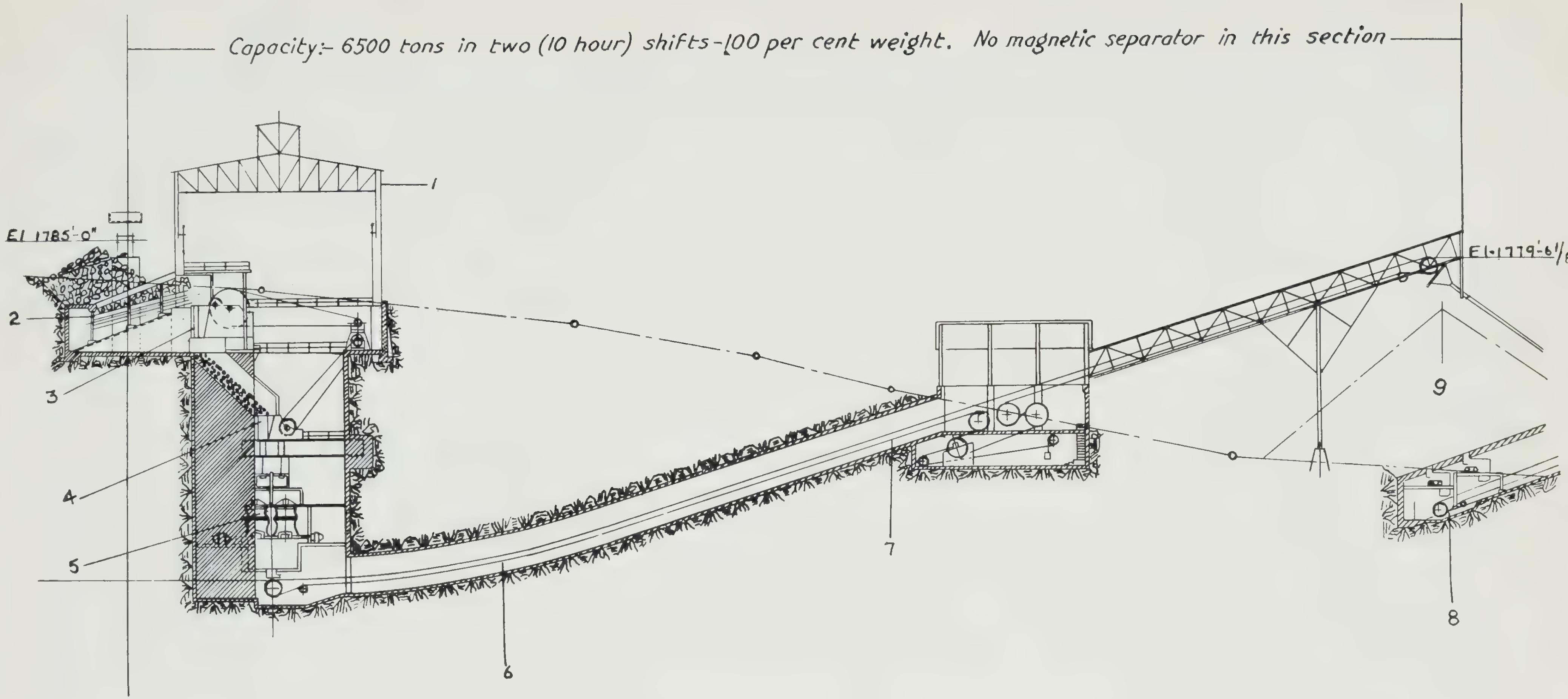
The 10-inch product then passes to a 36 by 54-inch jaw crusher and is reduced to about 4 inches. It then drops into a larger bin that has somewhat the function of a surge tank, since it provides for any unevenness in the flow from the jaw crushers to the following stage of reduction. From this bin the 4-inch product feeds to four No. 9 gyratory crushers, and is further crushed to a product passing a 2-inch ring.

A 42-inch conveyor belt takes this material to the first storage pile.

This completes the cycle of operations in the coarse crushing plant. It will be noted that it is dry crushing; no attempt has been made to concentrate, and the capacity is equal to about 10,000 tons per day from quarry size down to a diameter that will pass through a 2-inch ring.

Roll Crushing Plant

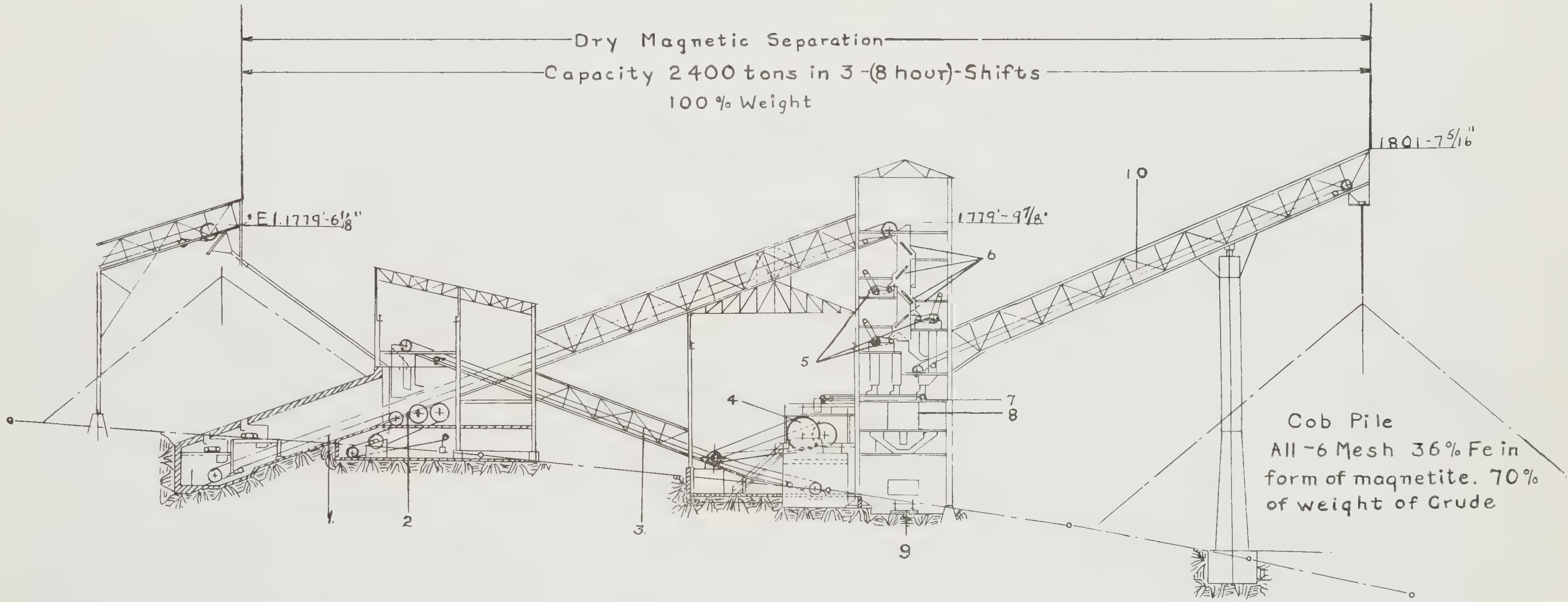
From the primary storage pile where the ore has been reduced so that it will pass a 2-inch ring, it is conveyed by apron feeders to a 30-inch conveyor, and from there to the top of a series of screens. The oversize from 2-inch screen passes direct to the rolls, while the undersize goes to a 1¼-inch Mitchell screen. The undersize from this screen passes to another series of screens decreasing



Total power consumption—1.9 kw.-hr. per ton reduced from steam-shovel size to 1½-inch product in the estimate. Power, Oct. 24th, 1.75 kw.-hr. per ton reduced.

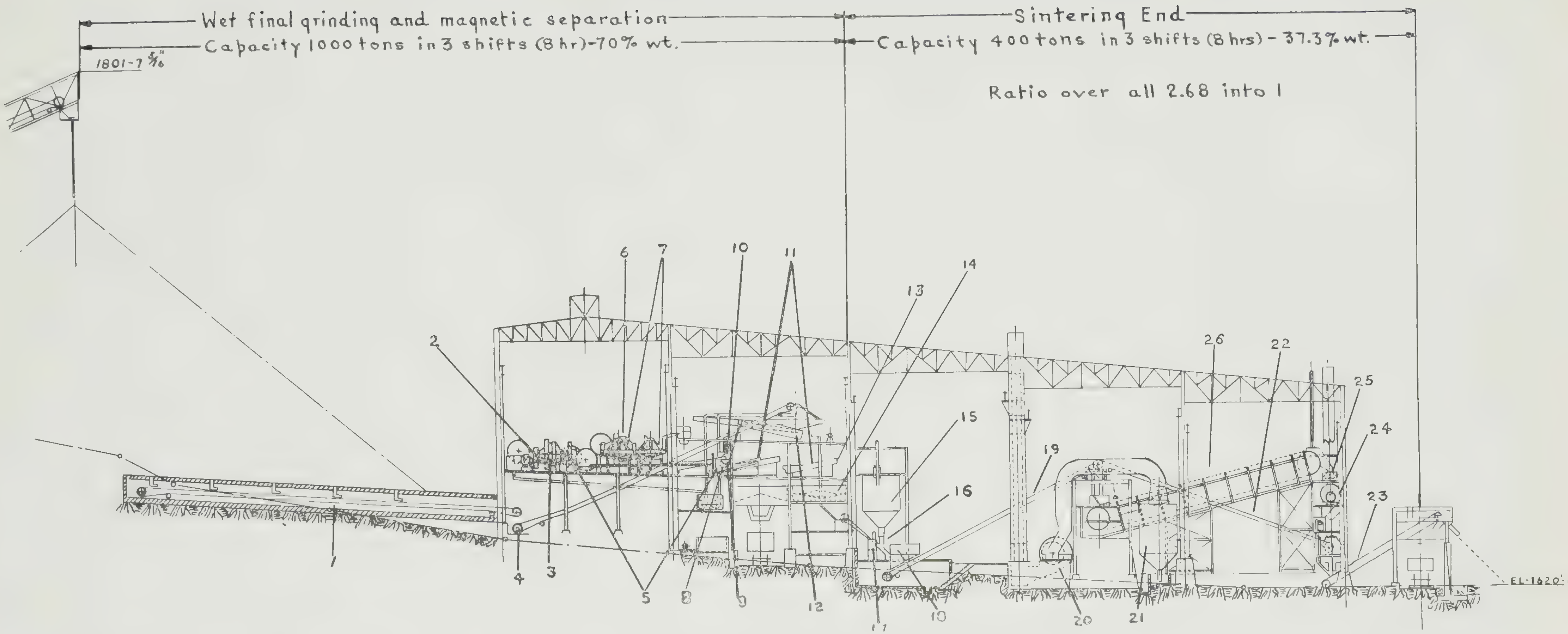
1—50-ton crane.
2—8 by 31 foot apron feeder.
3—48 by 72 inch steel jaw crusher; 170 tons weight, crushing 900 tons per hour to 12 inch.
4—36 by 54 inch steel jaw crusher; crushing 400 tons per hour to 6 inch.
5—4 gyratory crushers giving 1½-inch product; 100 tons each.
Note—12 inch, 6 inch and 1½ inch—minimum diameter of largest piece.
6—42-inch conveyor, 11 ply, 3/16-inch cover; speed 175 feet per minute; 397 feet centres, slope 18 degrees.
7—"Merrick" weightimeter.
8—Feeders.
9—Stock pile, capacity 3,500 tons net.

Fig. 17 (*a*)—Beneficiation plant, Mesabi Iron Company, Babbitt, Minn.



1—30-inch conveyor.
2—Conveyor drives.
3—24-inch return conveyor, for material not minus 6 mesh in size or minus 10 per cent. magnetic iron.
4—72-inch by 28-inch rolls.
5—Cobbers.
6—Screens.
7—Roll feeding conveyors.
8—Stone bins.
9—Rail track for stone eliminated.
10—18-inch "Cob" conveyor.

Fig. 17 (*b*)—Beneficiation plant, Mesabi Iron Company, Babbitt, Minn.



1—Tunnel feed 18-inch conveyor, capacity ≅ 40 tons per hour.
2—8-foot duplex classifiers, 1st stage.
3—1st stage mills and classifiers.
4—18-inch conveyor.
5—Wet cobber concentrate, minus 6 plus 48 mesh.
6—2nd stage ball mill.
7—8-foot bowl type classifier, 2nd stage.
8—Wet cobber waste.
9—Sand to wet cobbers.
10—Final tails.
11—Davis magnetic washers, one rake followed by log washer.
12—Initial classifier, plus 48 minus 6 mesh sand, minus 48 mesh overflow.
13—Final concentrate.
14—Dorr thickeners.
15—Sintering coal bin.
16—Coal feeder, 5-6 per cent, minus 30 mesh anthracite.
17—Concentrate measuring wheel.
18—Oliver continuous filter.
19—Filter cake conveyor.
20—100-inch fan, 350-h.p. motor.
21—Dust collector.
22—Sinter return conveyor.
23—Sinter cooling, loading metal conveyor.
24—Trommel. 25. Toothed rolls.
26—Sintering machine.

Fig. 17 (c)—Beneficiation plant, Mesabi Iron Company, Babbitt, Minn.

from stage to stage. The final undersize passes directly to the cob pile, while the oversize in each case is taken over to magnetic cobbers, so adjusted that they will throw out of the circuit all particles containing less than 10 per cent. magnetic iron. The concentrates in each case join the oversize from the first screen and are conveyed to a pair of rolls 78 by 20 inches. From the rolls they pass to a conveyor, and from the conveyor to a $\frac{7}{8}$-inch Mitchell screen. The oversize is in closed circuit and returns to the apron feeders, while the undersize from a $\frac{7}{8}$-inch screen passes to a 30-inch conveyor, and from there to a $\frac{3}{8}$-inch screen. The undersize of this goes to a $3\frac{1}{2}$-mesh Hummer screen; the undersize of each joins the cob from the first battery of screens, and all is conveyed to the fine storage (minus 6 mesh), cob material to be further treated in the fine grinding plant. The oversize from the $\frac{3}{4}$-inch Mitchell screen is taken over to a grader, as is also the oversize from $\frac{3}{4}$-inch Hummer screens. The tails in each case go to waste, or for road material, while the concentrates are taken to another pair of 78 by 20-inch rolls, are then dropped to a 24-inch conveyor, and are returned in closed circuit to the undersize from the $\frac{7}{8}$-inch Mitchell screen.

The cobber tails collected are run out on the collecting conveyors and are taken to a stone trommel with round holes three-sixteenths of an inch in diameter. The fines, or dust, are sold as road surfacing material and loaded directly into cars where markets are available, while the oversize to three-sixteenths of an inch is treated as marketable stone.

Fine Grinding Plant[1]

From the cob storage pile (minus 6 mesh) the ore is spread on an 18-inch horizontal and incline conveyor; water is added for the first time in the process, combining with the ore in a Dorr classifier, 6 feet by 21 feet 8 inches, set to overflow at minus 48 mesh, such overflow being conveyed immediately to the pumps. The sand, or plus 48 mesh, is taken to wet cobbers, where all material running less than approximately 8 per cent. magnetic iron is eliminated. The concentrate is conveyed through pipe launders to two 8-foot by 22-inch Hardinge mills, and from there by pipe launders to four 8 by 22 foot Dorr classifiers. The plus 48 mesh material is in closed circuit and is returned to join the concentrate from the wet cobbers. The minus 48 mesh joins a similar product overflowing from the first classifier and is pumped by 8-inch rubber lined pumps to a Dorr bowl classifier which splits the feed into two products, plus 150 mesh and minus 150 mesh.

The plus 150 mesh goes to an 8 foot by 22-inch Hardinge mill, and from there by pipe launders to a 9-foot Dorr bowl classifier; the sand running plus 150 mesh is kept in closed circuit and returned to the Hardinge mill, while the overflow, minus 150 mesh material, joins the overflow from the first-mentioned Dorr bowl classifier and flows into five magnetic rake washers; the tails from the rake washers go direct to waste, while the concentrates flow into the magnetic log washers. The tailings from these log washers are returned and join the minus 48 mesh material below the pumps, while the concentrates constitute the final wet magnetic concentrate.

From the log washers the magnetic concentrate flows to Dorr thickeners, below which fine anthracite screenings are added; the combined product is then dewatered by two continuous Oliver filters, 5 feet 4 inches by 10 feet. The

[1]As experimentation is being continuously carried on, the flow sheet has been changed in some parts since this description was written in March, 1923.

cake drops to a 24-inch belt conveyor, which in turn feeds it to a 42-inch by 64-foot Dwight and Lloyd incline type sintering machine, ignition being obtained by the use of kerosene oil. The sintered product is crushed and trommelled, the fines being returned for further sintering and the coarse material dropping on to an inclined metal conveyor where it cools and is elevated to the railway cars for shipment to the dock.

By reference to the vertical elevation of the plant, the process can be traced step by step from the introduction of the quarry product to the finished sinter.

By way of further explanation the following is introduced as a balanced metallurgical statement:—

Product	Weight	Magnetic iron assay	Magnetic iron units	Magnetic iron content
	per cent.	per cent.		per cent.
Roll Plant				
1. Rock	100.0	28.5	2,850	100.0
2. Cob	70.0	36.0	2,520	88.4
3. Stone	30.0	11.0	330	11.6
Fine Grinding Plant				
4. Cob	70.0	36.0	2,520	88.4
5. Primary classifier, sand	59.2	38.0	2,250	79.0
6. Primary classifier, overflow	10.8	25.0	270	9.4
7. Wet cobber concentrate	45.4	47.0	2,130	74.8
8. Wet cobber tailing	13.8	8.5	120	4.2
9. Line 6, plus line 7	56.2	42.7	2,400	84.2
10. Final concentrate	37.3	64.0	2,386	83.7
11. Final tailing	18.9	0.75	14	0.5

Ratio of concentration 2.68 into 1. Extraction 83.7 per cent.

The analysis upon which the Mesabi Iron Company offer their sinter for sale is as follows:—

	Dried at 212° F.	Natural
Iron	64.00	63.04
Phosphorus	0.027	0.027
Silica	9.00	9.00
Manganese	0.20	0.20
Alumina	0.67	0.67
Lime	0.10	0.10
Sulphur	0.005	0.005
Titanium oxide	0.03	0.03
Gain by ignition	1.83[1]	1.83
Moisture	......	nil

[1] Gain by ignition due to oxidation of magnetite into hematite.

It will be seen from this that mechanically prepared sinter is a very high-grade furnace product. The iron content is high. Phosphorus and sulphur are low, and silica has been reduced to nine per cent. These chemical qualifications added to the physical characteristics displayed by the hard, porous sinter would appear to make it a most desirable product for the blast furnace.

Because it is hard, and within the Bessemer grade, it ranks on the market with the Old Range Bessemer ore. Adding the bonus for 64 per cent. iron as against the base 55 per cent., and a similar bonus for exceptionally low phosphorus content, the selling price at Lake Erie points would be around \$7.47 per ton, as against a base price for Old Range Bessemer, 55 per cent. iron, of \$5.95, thus showing a margin of a little over \$1.52 per ton.

But there are additional advantages favouring the Mesabi Iron Company as compared with those companies producing a natural high-grade iron ore from, say, the hematite deposits of the western end of the same Mesabi range.

Stripping the hematite deposits is becoming increasingly expensive, and probably amounts to about 50 cents per ton shipped to-day. Royalties are payable, in many cases varying from 25 cents on State leases to over $1.50 per ton in some cases, with a probable average of around 60 cents per ton.

Taxation of mineral lands in Minnesota has been previously discussed in Chapter III. The combined taxation levied by state, county, and municipality to-day represents about 28 cents per ton shipped.

Summarizing then as follows:—

Market advantage in price of product	$1.52 per ton	
Reduced cost by reason of no royalty	.60 "	
Reduced cost by reason of little stripping, say	.40 "	
Reduced cost by reason of reduced taxation, say	.25 "	
Total advantage	$2.77 per ton	
The estimated selling price of Mesabi sinter at Lake Erie points is	$7.47	
Deducting:		
Rail freight		$0.86
Dock charges		.05
Vessel charges		.70
Unloading		.13
		$1.74
Net value at the mine		$5.73
Estimated cost of production		3.50
Leaves an indicated profit of		$2.23

It is to be noted, of course, that the estimated cost of production per ton of sinter ($3.50) is based on a daily capacity of 10,000 tons of rock. The present capacity is, perhaps, not over 1,000 rock tons per day, and the plant is essentially an experimental one beyond the primary crushing unit. But when mechanical difficulties and final adjustments in operating practice are solved, additional sintering units will be added, increasing the plant capacity to around 1,000 tons rock per day for each such unit added.

This committee believes that the plant has passed the strictly experimental stage, because the company has actually produced the finished product and, generally speaking, proved their estimate as to quality and cost of production. However, they are still in the adjustment stage. Changes in detail are here and there necessary, and it would be poor economy to proceed with additional units until this first one has been perfected. While our information is to the effect that nothing has developed that would seriously disturb their first estimated cost of production, the fact remains that until the whole plant is completed and the estimates proven by practice, the cost of $3.50 per ton of sinter is an estimate, and even if this figure were considerably increased, it would still leave a fair margin for profitable operation.

If we were to take a short-sighted view we would point out that delay in obtaining capacity production, with the cost of experimental work incident to a pioneer effort of this character, coupled with interest charges on capital investment, was laying a very heavy burden on an enterprise of this kind, where, at best, the margin of profit is narrow. However, in a situation such as we face to-day, where new and additional supplies of iron ore must be obtained if the world is to progress, there is no room for such a short-sighted view. We must

look well into the future, and when we examine the prospect in this attitude it is at once recognized that while Mesabi Iron Company's cost may move upward gradually subject to the trend of events, the cost of iron ore must rise more rapidly due to decreasing supplies, diminishing iron content, and a gradually increasing public demand for steel products.

On the whole, then, the relative commercial position of the Babbitt plant should become more advantageous as time passes.

Magpie Plant

At the Magpie plant where siderite ores are treated, two skips running in balance hoist the ore from the mine and drop it directly into a No. 8 Austin gyratory crusher. Crushed to less than six inches, the product drops to a grizzly where the oversize is split, half going to each of two No. 5 Austin gyratories, set to crush everything to pass a three-inch ring.

This three-inch product, by means of belt conveyors, is transferred to a series of bins, each with a capacity of 250 tons, located in the roast house. This completes the preparation of the ore for beneficiation proper.

Roast House Equipment

The roast house equipment comprises six units. Each unit, complete in itself, consists of a rotary kiln, connected at the feed end with a dust arrester and stack and at the discharge end with a rotary cooler, with the necessary apparatus for injecting the pulverized fuel under air pressure.

The kiln is essentially a cylinder, 125 feet long and 8 feet in diameter, lined with fire-brick. It is mounted at an inclination toward the discharge end, one-half inch per foot in length, in such a way that it can be slowly rotated.

The Roasting Process

As the mixture of fine coal, dust, and air strikes the hot ore near the discharge end of the kiln, it is ignited. This is the hot zone in the kiln, and a temperature of between 1,000°C. and 1,100°C. is maintained. Gradually, as the hot gases make their way to the upper or feed end, their heat is absorbed by the oncoming ore. Finally, in a comparatively cool state, these gases pass out of the kiln into a dust collector, and from there up a stack 100 feet high.

We have noted that the cold, raw iron carbonate ore, as it made its way along the kiln, absorbed heat and was finally raised to a temperature of 1,000°C., or just under its melting point.

This roasting process provides for, first, the removal of the carbon as carbon monoxide and carbon dioxide, and secondly, the oxidization and removal of most of the sulphur. The chemical reactions may be indicated as follows:—

$$2\ FeCO_3 + \text{heat} + \text{air} = Fe_2O_3 + CO + CO_2$$
$$2\ FeS + \text{air} = Fe_2O_3 + 2\ SO_2$$

The finished hot ore discharges directly into another rotary, 4 by 40-foot kiln, lined with fire-brick, to which cool air has ready access and in which the finished ore is gradually cooled before its discharge to the stock-pile, ready for shipment. The hot air resulting from this cooling process is used with the pulverized coal on the main kiln, and its heat thus conserved.

Results Obtained

The comparative analyses of the raw and beneficiated ore are about as follows:—

	Raw ore %	Finished product %
Iron	35.61	50.00
Phosphorus	0.01	0.18
Silica	7.28	8.91
Manganese	2.09	2.48
Sulphur	2.00	0.20
Lime, magnesia, alumina	12.00	17.03
Loss on ignition	30.00	nil
Moisture, less than	.....	1.00

At the time the process was adopted and installed, the Algoma Steel Corporation recognized that to keep within commercial limits, the capacity of each unit must be maintained at not less than 120 tons of finished product per day; that the fuel consumption must not exceed 250 pounds per ton of roasted ore; and that they must desulphurize the ore without raising the temperature to a point where the ore gets sticky and forms rings on the lining near the discharge end of the kiln.

In 1915, with the plant operating under very favourable conditions, the coal consumption was 271 pounds per ton of finished ore. In 1916 and 1917, the figures were 294 and 292, respectively. A reduction was effected in 1918 and 1919, bringing the consumption to about 282 pounds. However, with post-war conditions affecting operations, and comparatively poor coal, the 1920 figure was 328 pounds.

Moreover, the maximum continuous burden in the kiln was found to be about 23 tons and the maximum production per unit, 110 tons of finished product per day.

Under these conditions, and with iron ore prices in 1921 approaching pre-war levels, this method of beneficiation was no longer feasible, and the mine and plant ceased production March 1st, 1921. Thus ended the one effort made to beneficiate Ontario iron ores that approached commercial success.

Circumstances Favouring Magpie Operation

In conclusion it must be noted, in fairness to similar attempts, that the Magpie mine enjoyed one big advantage in the fact that the owners of the mine were also operators of blast furnaces, and in a position, if necessary, to absorb practically the whole Magpie production. Only those who have studied this advantage can appreciate its value.

Still another advantage in the single ownership of beneficiation plant and furnaces, is that the owner has access to actual furnace results, and is thus placed in a position to take commercial advantage of the favourable features of their product.

Sintering May Solve Problem at Magpie

If by substituting the Greenawalt or the Dwight and Lloyd sintering system for the kilns, costs can be sufficiently reduced to permit beneficiated siderites to meet competition in the open market, such deposits as the New Helen offer genuine promise and are worthy of early and active development.

Moose Mountain Plant

The Moose Mountain mine and mill are situated near Sellwood, on the C.N.R., about 25 miles north of Sudbury. The mine is described with some detail on page 161, and a very excellent map, showing the location and extent of the ore bodies, the mine location, and relative position and extent of the town-site, accompanies the report entitled "Iron Ore Occurrences in Canada," issued by the Department of Mines, Ottawa, in 1917.

The concentrating plant, or No. 2 plant as it is commonly called, is situated near No. 2 deposit, and the building itself takes, roughly, the shape of the letter "L" inverted. The short arm lies along the top of the hill, and the long arm extends down the hillside. In the upper building is housed the machinery for coarse, or primary, crushing, and extending downward is the fine grinding, concentrating, and briquetting equipment. The construction is mainly steel and concrete.

Grinding

The primary grinding was done by a Marcy mill, in which the ore is reduced from minus 3 inch to minus 8 mesh. The latter product was fed to two 6-foot Hardinge conical ball mills working in closed circuit with Dorr classifiers, the overflow from which constituted the finished product ready for magnetic separation.

Magnetic Separation

The concentration was effected by the use of Gröndal magnetic separators of the revolving drum type. These machines were grouped two in series and nine in parallel, thus making nine units of two machines each. The tailings drop into one launder and the concentrates into another, leading to the foot of an elevator where they are raised to a Dorr thickener.

Dewatering

The underflow from the Dorr thickener was conveyed to a 6-foot Oliver filter. The filter cake was partially dried before being dropped vertically into the briquetting press.

Briquetting and Kiln Burning

The concentrates were moulded in an ordinary brick-making machine, after which they were piled checker fashion on a steel car and pushed into a long kiln fired with producer gas.

The finished product, of the composition of hematite, was loaded on cars for immediate shipment, or conveyed to the stock-pile.

Results Obtained

Briefly summarizing the situation, a large sum of money was spent on what must now be looked upon as an incomplete experiment. It is generally conceded that the product was high grade. It is admitted by the company that the cost of such production was well above the price the furnace operators were willing to pay for it. Undoubtedly, if sintering instead of briquetting had been adopted, a considerable saving would have resulted, but whether such saving and the general application of improvements as ascertained and worked out during the experimental period of production, would permit production at a cost not in excess of the market value of the beneficiated ore, is a question that this committee cannot answer.

Trenton Plant

This plant was erected by the Canada Iron Mines, Limited, and in it they hoped successfully to treat their magnetic iron ores from the Bessemer, Childs, Coe Hill, and Blairton mines.

All ore was transported a distance of approximately 70 miles from the mines to Trenton, over the Bessemer and Barry's Bay Railway to Bessemer Junction, and thence by the Central Ontario Railway to its destination.

The mine ore, crushed to pass 2½ inches, was dumped from standard railway cars at Trenton into receiving bins, and from there elevated to a shaking screen. The oversize on three-quarter inch was passed through rolls working in closed circuit. All minus three-quarter inch was elevated to trommels. Minus one-sixteenth inch product was fed to the Gröndal wet magnetic separator, and the larger sized ore to three Ball-Norton drum type magnetic separators.

The furnace operators claimed that the concentrate contained an undue proportion of fines and that the sulphur content was excessive. The concentrate produced did not meet contract guarantees. To redesign the mill and provide sintering equipment required new capital, and operations were discontinued in September, 1913.

Atikokan Plant at Port Arthur

The ore developed at the Atikokan mine falls naturally into two classes high and low sulphur ores. Those described as low sulphur contain 2 per cent., or less, of that element.

So far as records are available, only low sulphur ore was shipped to the Port Arthur plant, where it was first subjected to treatment in Davis Colby roasters.

These bin-shaped roasters were described as having a maximum capacity of 31 tons per hour. It was claimed that the ore would make the passage through the roaster in forty-eight hours, and would gradually attain a heat of about 1,250° C. at the discharge end.

It was originally planned that this ore, when discharged, should be immediately transferred to the blast furnace, thus conserving heat. In actual practice this was found impossible, and practically all the ore was allowed to cool before going to the furnace. In any case, the process was a failure at the Port Arthur works of the Atikokan Company.

Ore Analysis

Following is the average analysis of all ore shipped from the Atikokan mine, 1908–1912:—

	Before roasting %	After roasting %
Silica	8.68	8.54
Alumina	1.51	1.55
Metallic iron	59.85	60.24
Phosphorus	0.11	0.11
Manganese	0.11	0.11
Lime (CaO)	3.00	3.15
Magnesia (MgO)	2.54	2.59
Sulphur	2.01	0.66
Copper	0.12	0.12
Titanium	nil	nil
Nickel	0.11	0.11

CHAPTER VIII

DESCRIPTION OF THE BLAST FURNACE

It is not known when iron was first used. Research only indicates its use by man through a period of about four thousand years. Actual evidence as to the extent of its use during the first three thousand years of this period is lacking, but it is probable that the metal was used more extensively than the few specimens so far uncovered would indicate. Iron is perishable, and because of its corrosive properties leaves no trail through the centuries.

It is not likely that if the use of iron or steel were discontinued suddenly on this continent, any evidence of its extensive use would be available a thousand years hence. Only occasionally is some implement or ornament found among ancient ruins.

Only doubtful evidence has as yet come to light of its use in the building of the Egyptian Pyramids about 4000 B.C., but positive proof exists that the ancient Hebrews and the Assyrians used it about 1400 B.C., and later the Greeks. Then the Romans became comparatively proficient in its metallurgy and spread throughout Europe the art of extracting and shaping, or working iron. Caesar, after crossing the English channel, found iron in use by the native Briton. During the Roman occupation the industry grew to one of importance in England.

The iron was obtained by heating a mixture of ore and charcoal, probably in a flat bottom furnace or forge, until there had collected a small body of pasty metal (sponge iron) which was then withdrawn from the furnace and worked by hammering to make wrought iron. This was the process used until 1350, when the iron makers of Central Europe succeeded in producing iron that would melt in the furnace and permit casting. They accomplished this in a different kind of furnace, one built of masonry enclosing a shaft or vertical opening, and having in a crude way the lines of the modern blast furnace. In this furnace, ore, flux, and charcoal were charged in at the top while air, under very low pressure, was blown in at the bottom. This method was introduced into England about 1500. In 1619, coke was first used as fuel, and about 200 years later the hot blast was introduced.

In 1619, the first iron works was established on the James river in Virginia, and about 100 years later the first blast furnace was built.

For about 100 years, or from 1700 to 1800, the furnaces were very crude affairs. Some of these are still standing in Virginia, the Adirondacks, and Pennsylvania. Most of them were about twenty to thirty feet high, of stone work, enclosing a circular shaft some four feet in diameter at the top and about eight feet at the bosh, the hearth either round or square in cross-section, the capacity ranging from one to six tons per day. By 1880 the output had increased steadily to nearly 100 tons per day, with a daily coke consumption of nearly 300 tons.

With all the basic principles in use, it is singular that so little progress was made in the industry during this period. About 1880, rapid development began, and to-day there are furnaces with a daily output of pig iron in excess of 600 tons, with a coke consumption of approximately 2,000 pounds per ton of iron.

No particular reference need be made here to unsuccessful attempts to found an iron industry in Canada, such as that by Molson on the St. Lawrence, at Moisie (Catalan forge), or of the early struggles of the little blast furnaces in Nova Scotia, at Sydney; in Quebec, at Radnor; or in Ontario, at Marmora.

Modern Improvements

A description of modern methods is made difficult by the complexity of the details involved in the process and by its recent rapid development. The fundamental principles have remained unchanged since the founding of the process, because experience has demonstrated that this process is the most practical. All improvements have been made with the object of increasing the production and at the same time decreasing the cost. These objects have been attained to a marked degree by the use of materials of the greatest purity, selected by chemical analysis; by increasing the size of furnaces; by economies in fuel; and by improved methods of handling material.

The comparatively simple small plants of 100 years ago have been succeeded by large complex affairs. The greatest changes have taken place since 1880, and because the improvements have been contributed by a great many men, different stages of development and different methods of attaining the same end are evident when visiting various works.

The Modern Blast Furnace

The modern blast furnace is a cylindrical steel shell, lined throughout with fire brick. It varies in height from 90 to 100 feet or more, and each furnace has varying diameters from top to bottom, the lines of the furnace being in this way adjusted to the various changes going on at different parts within it. The walls of the hearth near the bottom of the furnace are pierced with openings through which so-called tuyères convey a strong blast of heated air to unite with the carbon of the fuel.

Into the furnace top is charged continuously the ore, fuel, and flux which go to make up the burden. The ore furnishes the iron for which the furnace is operated. The fuel in burning gives off gases which serve to reduce the iron to a metallic form and to supply the heat required for the reactions which occur within the furnace, and to make fluid the desired product.

The flux serves to unite with various compounds which would otherwise be infusible at furnace temperatures, and to remove in a fluid state the ash of the coke and the earthy materials and impurities found in the ore. It also controls the quantities of certain elements which are required in the pig iron, but which are desirable only within certain limited percentages.

As the various materials of the charge work their way downward, approaching the hottest part of the furnace at or slightly above the tuyères, the various changes become more and more complete until fusion or a molten condition finally occurs. The molten iron, being heavier than the impurities, sinks to the bottom, while the impurities of the ore and ash, together with the limestone flux, combine to form a slag which floats on the surface of the iron. The two can then be easily tapped off separately through openings located at proper levels into pig-casting machines or ladles, depending on the kind of irons manufactured.

To carry on blast furnace operations on a large scale, extensive equipment is needed. The central feature of this equipment is the furnace, which is provided with apparatus for hoisting the charges to its top and with ladles for conveying

slag and molten metal, casting beds or pig machines for casting the metal into pigs of convenient size, and in some cases slag granulating pits. Next in importance follow the blowing engines for producing the blast, then the stoves for heating it. Another necessity is the pumping station, its part being to furnish large quantities of water for steam and cooling purposes. The gases generated in the furnace are combustible, and apparatus for their most efficient disposal is necessary. These gases are used to heat the stoves and to generate power by burning under boilers or in gas engines, in which case they must be cleansed of large quantities of flue dust. Modern equipment requires a stock house topped by bins in which ore, fuel, and flux are temporarily stored and conveniently removed for weighing or measuring before delivery to the top of the furnace. Adjacent to the bins will be located the stock-yard containing the ore pile, which is spanned by ore bridges. A car dumper advantageously situated usually completes this part of the equipment. Finally the various parts of the plant must be connected by a system of railways for transporting the materials.

Furnace

The furnace itself is usually considered under three main divisions, hearth, bosh, and shaft.

The Hearth

The hearth is essentially the basin or reservoir of the furnace for the molten iron and slag. It has a heavy brick lining which varies in thickness depending on the size of the furnace. The diameter and depth of the hearth also depend on these features. The outside of the hearth is reinforced by a heavy metal jacket, always cooled by water. The bottom is a solid mass of fire brick, 6 to 22 feet deep. In time metal replaces quantities of this brick, forming and collecting until it often weighs many tons. It is called the salamander.

Tapping Hole

This is the opening through which the iron is drawn off. It is usually located about two feet above the furnace bottom, at the front of the furnace or facing the cast house. The opening is closed with a clay mix which soon burns into place and seals the opening until it is broken out for tapping.

Cinder Notches

There is usually but one cinder notch, which is placed at from 45 to 90 degrees from the tapping hole. Its height above the furnace bottom determines how high the iron may reach before tapping. The opening is stopped by a tapered plug attached to an iron bar, which is withdrawn when it is necessary to flush off the slag.

Tuyères

Tuyères, 10 to 16 in number, through which the blast is admitted, are symmetrically placed around the upper circumference of the hearth just below the boshes and determine the height to which the slag may be allowed to rise. In larger furnaces this is usually about three feet.

Against the inner tuyère rests a horizontal cast-iron pipe, termed the blow-pipe, connecting in its turn with a pipe called the down leg or tuyère stock, which takes off from the bustle pipe encircling the furnace and supplying its blast.

The tuyère stock carries the blast from the bustle pipe to the blow pipe. It is usually in two sections of cast iron and has a thin lining of fire brick. An eye sight is located in the back of it and is closed by a piece of cobalt glass set in a small casting to allow of observation of hearth conditions, etc.

Bustle Pipe

The bustle pipe is a large cylindrical, sheet steel pipe, about 4 feet in outside diameter, encircling the furnace about 12 feet above the floor and distributing the hot blast to the tuyères. It is brick lined, 9 to 12 inches thick, and is suspended by brackets or straps from the furnace columns.

Hot Blast Main

The hot blast main is brick lined and about the same size as the hot bustle pipe. It carries the hot blast directly to the tuyères from the stoves and terminates in the bustle pipe.

Bosh

The bosh is that part of the furnace just over the hearth where the greatest diameter is attained. In standard bosh construction, starting at the top of the brick, 30 inches in thickness is stepped outward, externally, nearly 6 inches for each 12 inches of actual rise.

Each step-out is supported by means of a heavy steel band, or a pair of bands, completely encircling the bosh. In the brickwork there are inserted in horizontal rows about 2 feet apart, vertical bronze or copper cooling plates with a circulation of water, the plates in each row being about four or five inches apart. The bosh as a whole is the zone of fusion, and the stock as it approaches the zone becomes more and more pasty, occupies less and less space, and finally melts. Narrowing or closing in of the bosh thus aids in concentrating the softening and semi-molten mass before the tuyères and gives it support as well.

Mantle

At the upper limit of the bosh is the mantle, conforming to the shape of the furnace at that point and totally encircling it. The mantle is made up of heavy steel plates and angles upon which rests the weight of the stack. It is supported by a series of cast iron pillars or fabricated steel structures which rest on a foundation supported by the main furnace foundation. This construction allows the entire lower portion (bosh and hearth) to be removed without disturbing the rest of the furnace.

Shaft

The shaft is the part of the furnace above the bosh. Usually the inner wall of this shaft is divided in an imaginary way into three almost equal parts called the upper, middle, and lower inwalls. This portion of the furnace is surrounded by the usual riveted steel shell.

Furnace Lines

In modern blast furnace construction, the lines, or form of the inside of the furnace, are considered of great importance. Experience has shown that the lower inwall should rise vertically for several feet, the boshes should be

steep, and the upper inwall should drop vertically for a distance of about 10 feet from the stock line. Bosh angles are now being increased from about 25 to 80 degrees. These steeper boshes are a very great improvement. The use of sintered ore in large proportions in the furnace burden may necessitate still further modifications and changes in the lines of present furnaces, probably involving a decrease in diameter in order to take advantage of this new type of rich raw material.

Furnace Linings

The brick work which forms the hearth, bosh, and inwalls of a furnace are referred to as its trimmings. All the bricks used are made of fire clay and are known as hearth and bosh brick, inwall brick, and top brick. Each kind is made of such material and in such a way as will best adapt it to the conditions surrounding its use.

The hearth and bosh are required to resist a very high temperature and the action of flux and slag. Inwall brick must be able to withstand abrasion at a moderately high temperature, and top brick must resist the impact and abrasive forces of the charges as they are dropped at a comparatively low temperature into the furnace. In a large modern furnace, approximately 800,000 nine-inch bricks are required, and the average consumption of brick is a little more than two bricks per ton of pig iron produced.

Tops

Furnace tops are somewhat complicated affairs. An arrangement called bell-and-hopper, or cup-and-cone, is used in closing the top of the furnace by a large circular hopper, the smaller opening of which is closed by the bell, which can be lowered and raised at will. A second, but smaller, bell-and-hopper is located above the first and provides a gas-tight space of large size between the two. The raw material upon being hoisted to the top, is first dropped or dumped into the upper hopper, whence it may fall into the larger hopper below when the small bell is lowered. When the small bell is raised against the upper hopper, the large bell is lowered, and the charge falls into the furnace without the escape of gas. The bells are made of cast steel, in one piece, and of such a slope (45 to 50 degrees) as to permit the charge to slide off readily. They are usually supported from their top centres by means of a rod and a sleeve, each attached to a counter-balanced lever operated by means of a steam or air cylinder, or an electric motor, controlled from the ground. The large bell is attached to the rod and the small bell to the sleeve. The details of this construction differ somewhat to conform to new improvements, to the type of hoist, and to the ideas of the different builders.

Stock Distributor

One of the alleged improvements in the bell-and-hopper device is that of the stock distributor. In a mechanically-filled furnace, when the raw materials are dropped into the receiving bell, the larger lumps of ore and stone will have a tendency to roll and thus collect either around the edge or to one side. The same thing will also happen upon dropping the charge into the furnace. This tendency results in more or less open and continuous channels being formed through the materials and extending from the top to the bottom of the stack. These channels, of course, offer the least resistance to the passage of the blast. This condition, called channelling, results in higher temperatures throughout

these passages, with the consequent cutting away of the walls where they come in contact with them. It is to overcome this defect that the various devices known as stock distributors have been designed.

Hoisting Appliances

There are two types of hoist used, the skip hoist and the bucket hoist. In both cases there is an incline, a fabricated steel structure extending from the top of the furnace to or below the bottom of the stock house. Over the tracks of this incline pass the materials charged into the furnace. In the skip hoist the conveying vessel is a small, open ended steel car, called a skip, that automatically dumps the materials upon the little bell-and-hopper. In the bucket hoist the solid materials are raised in a bucket, suspended from a truck or carriage, that drops the charge directly into the space above the large bell. When in position for dropping the charge, the bucket, being itself provided with a small bell at the bottom, takes the place of the bell-and-hopper. During the time the bucket is filling at the stock house, the opening left in the top is closed with a special gas seal.

Runners

The runners are metal castings in the form of deep troughs made in sections laid end to end and buried so that their top edges are flush with the floor of the cast house. The trough leading from the cinder notch is elevated. It forms an uninterrupted passage for the slag from the cinder notch to the slag ladle or granulating pit. Beginning at a very deep trough at the tapping hole, the molten metal is interrupted at the end of about 10 feet by the skimmer, a device for separating the metal from the slag in the mixed flow that comes near the end of the cast. There are two branches here, one for carrying away the slag and another for draining the metal from this part of the skimmer trough after the cast. Before casting, these troughs are given a heavy coating of a loam or clay wash which acts as an insulator, protects the trough from the hot metal, and facilitates the subsequent cleaning up. Without this wash, the hot metal would either chill in the trough or melt it away.

The Stoves

There are nearly always four stoves to a furnace, and they are first in importance after the furnace itself, as they heat the blast. The stove is a brick-walled cylinder enclosing a combustion chamber and a system of regenerative flues. Outside, the brick wall of the stove is reinforced and supported by a steel shell of riveted plates; the top is dome-shaped. The stoves are generally as high and almost as wide as the furnace itself, and hey vary in size with the size of the furnace. For the largest furnace they are approximately 100 feet in height and 22 feet in diameter. Internally, the combustion chamber extends from the bottom to the top o' the stove and may be located at the centre, in which case it is called a centre combustion stove, or at the circumference as in side combustion stoves. The regenerative flues are filled with brick checker work, the checkers being so laid as to form a system of vertical flues, from five to nine inches square, which extend from the rider walls on the bottom to the top of the stove. Stoves in which the gases from the combustion chamber pass through only one regenerative flue, are called two-pass stoves, while in three-pass and four-pass stoves they pass through two and three regenerative flues, respectively.

Dust Catcher and Gas Mains

From the downcomer, the gas from the top parts of the furnace top passes directly into the dust catcher. Its object is to clean the gas as much as possible of the flue dust blown over from the furnace, with which the gas is heavily 'aden. If this dust is not largely removed, it cakes upon the walls of the combustion chamber, chokes the small flues of the stoves, and, dropping down, necessitates frequent cleaning and delays. It also acts as an insulator on the brick, preventing the full absorption of heat. The dust catcher is often 20 feet or more in diameter. The principle involved in its construction is that of greatly reduced velocity, accompanied by sudden changes in direction.

Equipment for Handling Raw and Finished Materials

The boiler house, power plant, pumping station, blowing engines, etc., while constituting a vital part of the blast furnace equipment, present features of more interest to engineers than to metallurgists and are, therefore, best omitted from this discussion.

Dry Blast

About 60 per cent. by weight of all the materials entering the blast furnace is air. As air always contains moisture and as the decomposition of water is an endothermic reaction, the heat absorbed by the water thus entering the furnace may be very great. It has been estimated that during the month of July, for instance, the average quantity of water, per hour, entering a furnace using 40,000 cubic feet of air per minute is approximately 224 gallons. That this quantity of water may seriously affect the operation of the furnace is now well recognized, and installations for drying the air have been made at a few plants. The principle employed is that of refrigeration. By cooling the air at a low temperature and by drawing it over a system of pipes cooled with brine (a solution of common salt which is cooled with liquified ammonia), the moisture is condensed and frozen on the pipes, leaving the air practically dry.

Cold and Hot Blast Mains

It is still the most common practice to use undried air which, compressed by the blowing engines, is normally forced under the high pressure of about 15 pounds per square inch, through the cold blast main into the stoves from which it issues highly heated, passes successively through the hot blast main, the bustle pipe, and the tuyères, and begins its work in the furnace. Leading around the stoves from the cold blast main into the hot blast main is a small pipe, called the by-pass, which provides a means for controlling the temperature of the hot blast.

Stock-House Equipment

All materials charged into the furnace are accurately weighed in the stock-house. These weighed materials, ore, stone, or coke, are delivered to the skips by a small-track trolley hopper car with scale attachments.

Disposal Equipment for the Iron

For casting the iron the endless chain machine, carrying a series of parallel molds or troughs with overlapping edges, is commonly used. The molten metal from the furnace flows into ladles which are pulled into the casting house. Here the metal is poured slowly into a trough from which it flows onto two lines of moving moulds which are "limed" or "smoked" to prevent sticking of the iron.

The chains carry the iron directly through a trough of water, or dump the half cooled pigs upon a second conveyor to be so cooled.

Equipment for Slag Disposal

Large quantities of slag are produced. This is either run into special ladles and used for fills or road material, or else run into pits filled with water. It can sometimes be used for making Portland cement.

Pig Iron

Pig iron is a product of the blast furnace and is so designated because of the fact that the hot fluid metal on being tapped from the furnace runs through the cast house in a long sand trough from which smaller troughs branch at right angles, these in turn being broken into by moulds into which metal runs, forming, when solid, a sand-cast pig.

The later and up-to-date furnaces are equipped with casting machines. These do not require casting in the sand, and the resulting product is shipped to the foundry without any adherence of sand or kish.

Iron for use in the open hearth, or direct foundry casting, is run into large ladles carrying sometimes over 50 tons, and transferred molten to the department in which it is later to be used. This type of iron is called hot metal.

Pig iron is classified according to the method of manufacture, the purpose for which it is intended, and its composition. Formerly it was graded by fracturing the pig and examining it, but this method has been largely superseded by chemical analyses, and in Canada to-day practically all iron is sold by this latter method.

Each country has different methods of grading and classifying. English practice is different from United States practice, and that followed in Canada differs from both.

There are two outstanding or commonly used grades of foundry pig iron, and the others in less common use are regarded in most cases as specials. A very large tonnage of basic pig iron is made for use in the basic open hearth steel processes. The analysis of this varies according to the ideas of the purchaser. A very much smaller tonnage of Bessemer pig iron is used for making acid open hearth steel. Both of these latter types are regarded as specials.

STANDARD ANALYSIS OF PIG IRON

Grade	Analysis			
	Silicion	Sulphur	Phosphorus	Manganese
	per cent.	per cent.	per cent.	per cent.
No. 1 Foundry (adapted for stove plates, locks, and thin castings generally)	2.25 to 2.75	0.04 and under	0.50 to 0.80	0.55 to 0.80
No. 2 Foundry (adapted for agricultural implements, machinery, radiation and all classes of work requiring toughness, stiffness, density, and for general foundry castings)	1.75 to 2.25	0.05 and under	0.50 to 0.70	0.50 to 0.70
No. 3 Malleable Bessemer (adapted for malleable castings)	1.00 to 2.00	0.05 and under	0.20 and under	0.50 to 0.80
Basic open hearth	under 1.00	under 0.05	usually under 0.50	....
Bessemer	1.00 to 2.00	not over 0.05	not over 0.01	....

Below is a copy of the latest tentative specification of the American Society for Testing Materials, which is the result of the co-operative action between the A.S.T.M., the American Foundrymen's Association, and many other bodies, in an effort to obtain uniformity in manufacture, grading, and sale of pig iron.

There is another product of the blast furnace, namely, ferro-manganese. This is an iron with an excessively high manganese content, usually over 60 per cent., the standard of which is guaranteed to average 80 per cent. or over. It is produced by running the furnace on special ores at an exceptionally high temperature.

The analysis of an average representative American ferro-manganese is as follows:—

	Per cent.
Manganese	80.20
Iron, by difference	12.18
Silicon	0.66
Phosphorus	0.16
Sulphur	Trace
Carbon	6.80

Specifications for Foundry Pig Iron

The American Society for Testing Materials has issued (1922) specifications for foundry pig iron. This is a tentative standard only, published for the purpose of eliciting criticism and suggestions. It is not a standard of the society, and until its adoption as standard it is subject to revision.

I. Manufacture

1. The pig iron shall be clean foundry pig iron, as free as possible from an excessive amount of dross and sand, and may be either sand or machine cast.

II. Chemical Properties

2.—(*a*) The pig iron shall conform to the chemical requirements specified by the purchaser at the time of purchase, with the following permissible variations from the specified percentage:—

	Variation from specified percentage
Silicon	0.25 per cent. above and below
Sulphur	not over specified percentage
Total carbon	not less than specified percentage
Manganese	0.20 per cent above and below
Phosphorus	0.15 " " "

(*b*) The percentage specified for phosphorus and manganese may be used as maximum or minimum figures, but unless so specified they shall be considered to be subject to the variations given below.

III. Sampling and Analysis

3.—(*a*) In sampling, each carload or its equivalent shall be considered as a unit.

(*b*) One pig shall be taken to every four tons in the car, and they shall be so chosen from different parts of the car as to secure, as nearly as possible, a sample representing the average quality of the iron.

(*c*) The pigs thus taken shall be sampled by drilling so as to fairly represent the composition of the pigs as cast.

(*d*) An equal weight of the drillings from each pig shall be thoroughly mixed to make up the sample for analysis.

4. It is recommended that analyses be made in accordance with the Standard Methods of Sampling and Chemical Analysis of Pig and Cast Iron (Serial Designation, A 64) of the American Society for Testing Materials.

IV. Inspection and Rejection

5. In case of dispute, the sampling and chemical analysis shall be made in accordance with the Standard Methods of Sampling and Chemical Analysis of Pig and Cast Iron (Serial Designation, A 64) of the American Society for Testing Materials, by an independent chemist mutually agreed upon, if practicable, at the time the contract is made, whose decision shall be final. The cost of such re-sampling and re-analysis shall be borne by the party in error.

6. All pig iron which fails to conform to these specifications shall be subject to rejection.

Code

In using these specification it is not advised that all five elements be specified in all contracts for pig iron, but it is recommended that, when these elements are specified, the following percentages be used. For convenience the accompanying code is endorsed:—

SILICON

Per cent.	Code
1.00	La
1.50	Le
2.00	Li
2.50	Lo
3.00	Lu
3.50	Ly

(0.25 allowed either way)

SULPHUR

Per cent.	Code
0.04	Sa
0.05	Se
0.06	Si
0.07	So
0.08	Su
0.09	Sy
0.10	Sh

(Maximum)

TOTAL CARBON

Per cent.	Code
3.00	Ca
3.20	Ce
3.40	Ci
3.60	Co
3.80	Cu

(Minimum)

MANGANESE

Per cent.	Code
0.20	Ma
0.40	Me
0.60	Mi
0.80	Mo
1.00	Mu
1.25	My
1.50	Mh

(0.20 allowed either way)

PHOSPHORUS

Per cent.	Code
0.20	Pa
0.40	Pe
0.60	Pi
0.80	Po
1.00	Pu
1.25	Py
1.50	Ph

(0.15 allowed either way)

Illustration of the use of above coding: The word Li-se-ca-mo-pi indicates the following percentages:—

Silicon	Sulphur	Carbon	Manganese	Phosphorus
2.00	0.05	3.00	0.80	0.60

with variations allowed.

Percentages of any element specified half way between the above shall be designated by the addition of the letter "X" to the next lower symbol.

Example: PeX indicates phosphorus 0.50 with allowed variations (0.15) and down.

CHAPTER IX

MAGNETITES AND SINTER IN THE BLAST FURNACE

Non-Titaniferous Magnetites

Since Mesabi ores became the most important source of iron in America, there has apparently developed among the users of these ores a certain prejudice against magnetites, or perhaps it would be better to say, a pronounced preference for hematites for use in the blast furnace. In the Eastern States there has grown up again in recent years, however, a considerable iron ore industry founded on the magnetites of Pennsylvania, New Jersey, and New York state. A few years ago the blast furnace of the Witherbee, Sherman Company at Port Henry was probably the only blast furnace using magnetite exclusively.

Magnetite is a denser ore of iron than is hematite, and its reduction is more difficult. This difficulty in reduction of magnetite is ascribed to its physical character rather than to its composition, for hematite passes through the lower oxide stage in the furnace. Very coarse magnetite would be objectionable in an iron blast furnace, because the surface presented to reduction would be small compared to the weight. For this reason furnaces treating magnetite use the ore in small sizes. On the other hand, very small magnetite, or fine magnetite, runs ahead of reduction in the iron blast furnace and at times reaches the hearth unreduced. The Witherbee, Sherman Company at Mineville, N.Y., do not resort to very fine crushing, and so their magnetite concentrates do not contain any extremely fine material. These are the concentrates that are smelted raw on the blast furnace at Port Henry, and this Port Henry furnace is operating very successfully on this material.

The difficulty of reduction of the magnetite is offset by the high iron content of the charge, so that the coke requirements per ton of pig will compare favourably with Mesabi practice.

The furnaces of the Replogle Steel Company at Wharton, N.J., are running a charge consisting of coarse magnetic concentrates and sinter. The charge is about 80 per cent. magnetite and about 15 per cent. sinter. In speaking of it, H. J. Briney, the blast furnace superintendent, said that this was an easier operating furnace charge than would be a charge of Mesabi ore. His previous experience before coming to Wharton had been, he stated, exclusively with Mesabi ores.

At Birdsboro, Pa., the furnace of the E. and G. Brooke Company is smelting regularly a charge containing 85 per cent. of sintered, crushed magnetite. Their coke consumption would compare very favourably with a furnace using Mesabi ores. The Birdsboro furnace, too, was a small one, with a 12-foot hearth. Furnace men emphasize the even working of the furnace and freedom from slips.

At Standish, N.Y., the Chataguay Iron Company is using sintered magnetite concentrates up to 100 per cent. of the charge.

Briquettes made from Moose Mountain magnetite concentrates have been successfully smelted in the blast furnace of the Steel Company of Canada at Hamilton, as described fully in Chapter XII of this report (see page 89). The same concentrates made into sinter would be more desirable for the furnace operation (see page 92).

Undoubtedly the sinter is ideal material for a blast furnace. It is rough and angular, and presents a maximum of surface for reduction. It is a comparatively new material in the iron blast furnace charge, and very few furnace men have had any experience with it. Some furnace men who have used magnetite express a dislike for it in the furnace, but sinter appears to be possessed of very desirable characteristics.

As it appears that sinter is most likely to be the form in which the product of the known Ontario iron deposits will reach the market, the province will watch with interest the development of the use of sinter in the iron blast furnace.

Titaniferous Magnetites

To the extent to which magnetite contains titanium is its iron content lowered and its value as an iron ore lessened. So far the mechanical concentration of magnetites containing titanium has met with very little success. There are deposits of magnetite containing small percentages of titanium, and still containing enough iron to make them apparently valuable as iron ore.

There is a very pronounced prejudice, whether warranted or not, in the minds of blast furnace superintendents against even a very small amount of titanium in the charge. Titanium is supposed to make a pasty and difficult slag. It is supposed to form accretions, particularly a red nitrocyanide of titanium, in the hearth of the furnace. In the early days of the iron industry in the Adirondacks, however, very considerable tonnages of titanium-bearing magnetites were successfully treated in small charcoal iron furnaces. It is very doubtful if it was known at that time that titanium was present in these iron ores.

A. J. Rossi has been a painstaking investigator of the blast furnace treatment of titaniferous magnetites, and the results of his experiments are to be found throughout the literature on the subject. There is no doubt that Rossi made a very thorough success in his blast furnace experiments. It is true that he was operating a very small furnace, but that does not detract in any way from his success, as it requires greater skill to operate a small furnace.

Following the success of Rossi, a large scale test was made in 1914 at Port Henry, N.Y., under the superintendence of F. E. Bachman. A complete account of the result of this run of titaniferous magnetite was presented by Mr. Bachman before the American Iron and Steel Institute. Among Mr. Bachman's conclusions is this statement:—

> Titaniferous concentrates are reduced in the furnace with no greater, and probably with less expenditure of heat and consequently of fuel, than non-titaniferous magnetites.

The success that both Rossi and Bachman had in smelting titaniferous magnetites seems to have been due, for one thing, to their fluxing of titanium as an acid. The result of the examination of the Port Henry furnace for characteristic accretions, after the campaign, is given in Mr. Bachman's words, as follows:—

> Nitrocyanide of titanium was looked for very carefully, but none could be found in any place, with the exception, possibly, of a few copper-coloured crystals which one of the foremen reported having seen in the layer of fused brick in the extreme bottom. He, however, did not retain this, so that the presence of this compound in any portion of the hearth is uncertain.

Notwithstanding the success of the Port Henry campaign, little if anything has since been done in the way of smelting titaniferous magnetites, and there is no doubt that a prejudice against their use still exists among blast furnace operators. If a shipment of magnetite containing over 1 per cent. of titanium, but otherwise unobjectionable, were offered to any blast furnace plant in Canada at the present time under any reasonable terms, it is doubtful if the lot could be sold. Until such a time as a younger generation, less imbued with the traditional prejudice against titanium, shall have grown up, it would seem to be unwise to spend money on magnetites containing titanium, with a view to their reduction in the blast furnace. The comments of some iron blast furnace

men on the success of Rossi and Bachman, would lead one to think that they preferred not to be convinced of the feasibility of smelting titaniferous magnetites. It is true that a great many difficulties, and some failures, have been encountered in the smelting of titaniferous magnetites by others than Rossi and Bachman, and no doubt some other successes, or partial successes, have been made. But the failure of one man where another succeeds would indicate not that the thing could not be done, but that the man who failed did not know how.

Apparently an electric furnace man has no particular prejudice against the treatment of titaniferous magnetites. However, the electric smelting of iron ores is still in its infancy, and what possibilities lie in this direction are still to be demonstrated. At Sault Ste. Marie, experiments with electric furnaces for smelting iron ores were made by Dr. Haanel for the Canadian Government, and in one of these experiments titaniferous magnetite was used. Dr. Stansfield has written concerning the electric smelting of titaniferous magnetites, and Mr. J. W. Evans, in his electric furnace at Belleville, has carried out experiments with such ores.

Appended to this report is a bibliography on the subject of smelting titaniferous iron ores which will enable those more particularly interested to become informed of what has been done and written on the subject.

CHAPTER X

BLAST FURNACE SUPERIOR TO ALL KNOWN SPECIAL PROCESSES FOR REDUCTION OF IRON ORE

Electrolytic Iron from Iron Anodes

There have been various methods suggested for producing iron electrolytically, but most of these have not gone beyond the laboratory stage. During the war period there was in operation a plant at Grenoble in France for the production of electrolytic iron. This plant used an iron anode and an electrolyte of ferrous chloride. It was, therefore, a refining process, making from cast iron and mild steel a pure iron. This plant has a capacity of one ton of electrolytic iron per day and is still in operation.

Electrolytic Iron from Steel Anodes

The Western Electric Company have a plant at Hawthorne, Ill., for the production from steel anodes of electrolytic iron. They used a mixed chloride and sulphate bath or electrolyte. Their electrolytic iron is used for magnet cores for telephones. This plant has a capacity of two tons per day and is the only example of commercial production of electrolytic iron on the continent.

Electrolytic Iron from Ores by Eustis Process

A very interesting process for the production of electrolytic iron from ores has been patented by F. A. Eustis. The ore best suited for the process is pyrrhotite. S. G. Blaylock experimented with this process at Trail, B.C., and made some very excellent iron from the pyrrhotite tailings of the Sullivan ore. The Eustis process has passed the laboratory stage of its development, and an experimental plant with a capacity of one ton per day will soon be in operation at Milford, Conn. It is interesting to know that the ore to be used in this plant comes from Quebec. The electrolyte consists of a ferrous chloride solution containing 180 milligrammes of iron per litre. An insoluble carbon anode is used, which is surrounded by a diaphragm. The bath is maintained at a temperature of about 100°C., and electrolysis proceeds until 20 per cent. of the iron has been deposited. The electrolyte will then consist of 72 grammes of ferrous iron and 72 grammes of ferric iron per litre. This liquor constitutes the leaching solution for the finely ground pyrrhotite ore. Leaching is conducted in agitators at a temperature of about 100°C. The reaction between the ferrous chloride and the pyrrhotite is represented by the equation $FeS+2FeCl_3 = 3FeCl_2+S$. The iron goes into solution and the insoluble material consists of the gangue in the ore and the sulphur. This is removed as a filter cake. The process appears to be perfectly feasible. Neither the leaching end nor the electrolytic end would appear to present unusual or insurmountable difficulties. In pyrrhotite we often find copper, zinc, lead, nickel, and cobalt. Copper is dissolved by the solution, but is easily removed by cementation on scrap iron, and would be a by-product. Zinc, lead, nickel,

and cobalt may be removed by precipitating with calcium sulphide; at least this appears to have been successfully done in the laboratory. Three types of electrolytic cell are to be used in the Milford plant. In the first type there is a rotating horizontal mandril, 12 inches in diameter and 12½ feet long. This will run wholly immersed in the electrolyte and will produce 100 pounds of electrolytic iron per day at the current density to be employed. Electrolytic iron contains hydrogen and is brittle. The hydrogen may be driven off by annealing at a comparatively low temperature, when the iron becomes ductile and malleable. These tubes will be used for the production of seamless tubes which may be drawn to varying diameters. A second type of cell employs a larger mandril, rotating on a vertical axis, and a third type will deposit the iron on vertically hanging sheets or plates. The surface of the iron is very smooth, and the tubes after removal have much the appearance of a rolled sheet. The iron is extremely pure and is possessed of characteristic physical properties which make it desirable for certain industrial uses. For pipes and tubes, for metal for stamping, for transformer sheets, and as very pure material for the production of crucible steel and special alloy steels, it might find a field.

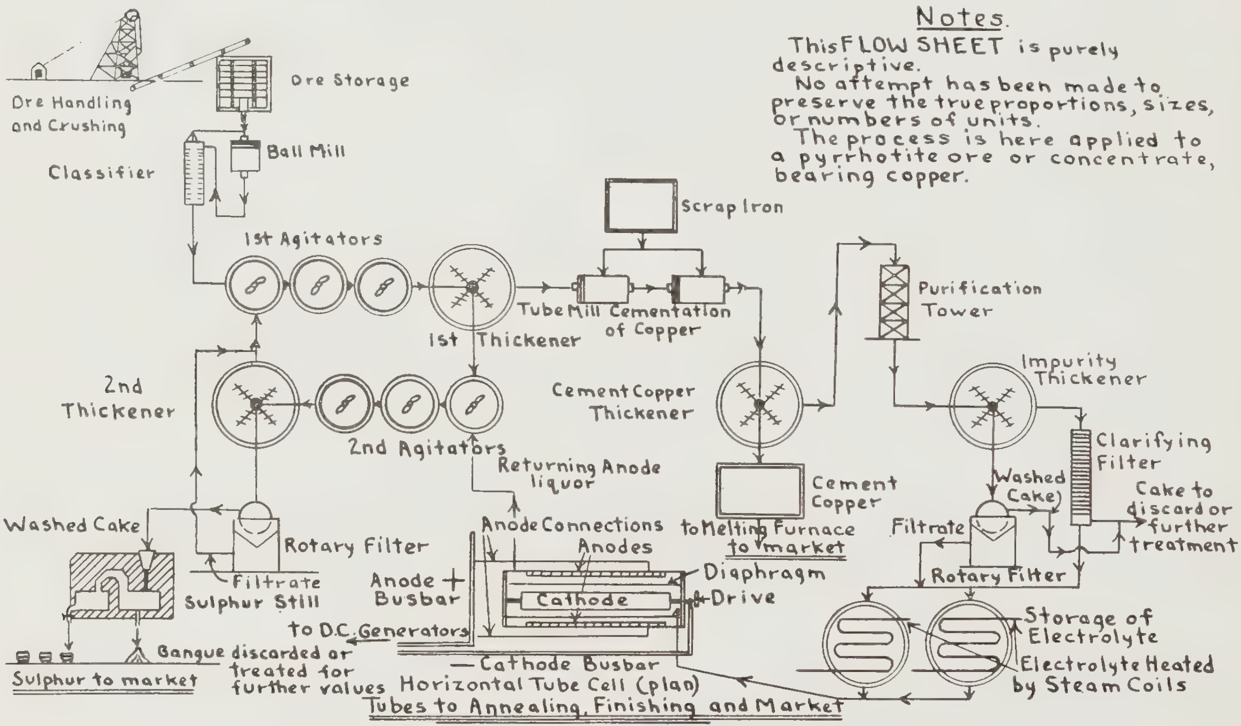


Fig. 18—Flow sheet of Eustis process.

Until the plant at Milford has been in operation it would be difficult to arrive at costs, but it has been estimated that this iron may be made for from fifty to fifty-five dollars per ton with power at twenty-five dollars per horsepower year. One horsepower year will produce 5,000 pounds of iron. Mr. Eustis is a metallurgical engineer who has been operating for many years in copper and in iron and the fact that he has associated with him in this Milford enterprise, Mr. C. P. Perin, senior member of the firm of Perin and Marshall, one of the very large firms of consulting iron and steel metallurgists on the continent, gives to the venture at once a standing that new ventures seldom have.

It would seem that if the process is thoroughly demonstrated as a commercial possibility, it might have very great interest for us in Ontario, as we have a pyrrhotite containing copper and nickel. The copper, the nickel, and the iron would be dissolved by the chloride leach liquors. The copper would be

precipitated as metallic copper, and then the nickel as nickel sulphide. There are, too, great possibilities in the value of the sulphur that might be recovered from the filter cake. This apparently carries upwards of 60 per cent. sulphur, and sulphur is an important raw material in the pulp and paper industry of our northern country.

The process does not, however, offer any solution for an iron ore industry as a whole, nor for those deposits which at the present time may be considered potentially as iron ores, that is, our hematites and magnetites, as the process is not applicable to these.

Electrolytic Iron from Ores by the Estelle Process

The issue of the Canadian Mining Journal of October 6, 1922, contains an article by Axel Estelle on the Estelle process for the production of electrolytic iron from ores. Axel Estelle is the patentee of the process. The article takes exception to the chemistry of the Eustis process, and points out that the essential leaching reactions of the Eustis processs do not occur. The article then goes on to describe the Estelle process for the treatment of sulphide iron ores. The net result of the leaching by the Estelle process is practically the same as in the Eustis process. The Estelle process is carried out in two stages. The pyrrhotite is leached with hydrochloric acid, according to the equation $FeS+2HCl=FeCl_2+H_2S$, producing ferrous chloride and H_2S gas. The H_2S gas is passed into an absorption tower where it reacts with the ferric chloride which is produced in the electrolytic cell. The reaction between ferric chloride and H_2S is expressed by the equation $2FeCl_3+H_2S=2FeCl_2+2HCl+S$. If the leaching reaction essential in the Eustis process does not take place, there would seem to be no reason for using an acid leach and recovering sulphur in the tower from sulphuretted hydrogen gas. In addition to the Estelle process for treatment of sulphide ores as shown in this article, Mr. Estelle has a process for the production of electrolytic iron from oxide ores.

The bath he uses is a hot slime of iron hydroxide and caustic soda containing 30 per cent. iron oxide, 35 per cent. caustic soda, and 35 per cent. water. This is electrolyzed without a diaphragm at a temperature of about 100° C., and as the iron is deposited, more ferric hydrate is added to the bath. Mr. Estelle states the necessity of having an extremely high-grade and finely-divided iron ore, such as may be produced by mechanical concentration of magnetites. Obviously, concentration must be relied upon to remove any impurities. The consumption of electrolytic power in this process is very high and preliminary concentration is required. At the present time this process is applicable only to magnetites.

The Metallizing Process

We, in Ontario, frequently hear the comment that our blast furnaces are using American and not Ontario iron ores. This is coupled with the reference to our lack of fuel. Our waterpowers are spoken of as sources of cheap electric power, and then the thought is voiced that through the medium of electricity there may be worked out a means whereby iron may be made from such of our ores as are unsuited to the blast furnace, at prices that would permit competition from blast furnace iron.

There must be a way and some process must be found: Such is the hope. Among processes other than that of the blast furnace, may be mentioned metallizing. A metallizing process is a process in which the iron ore is reduced

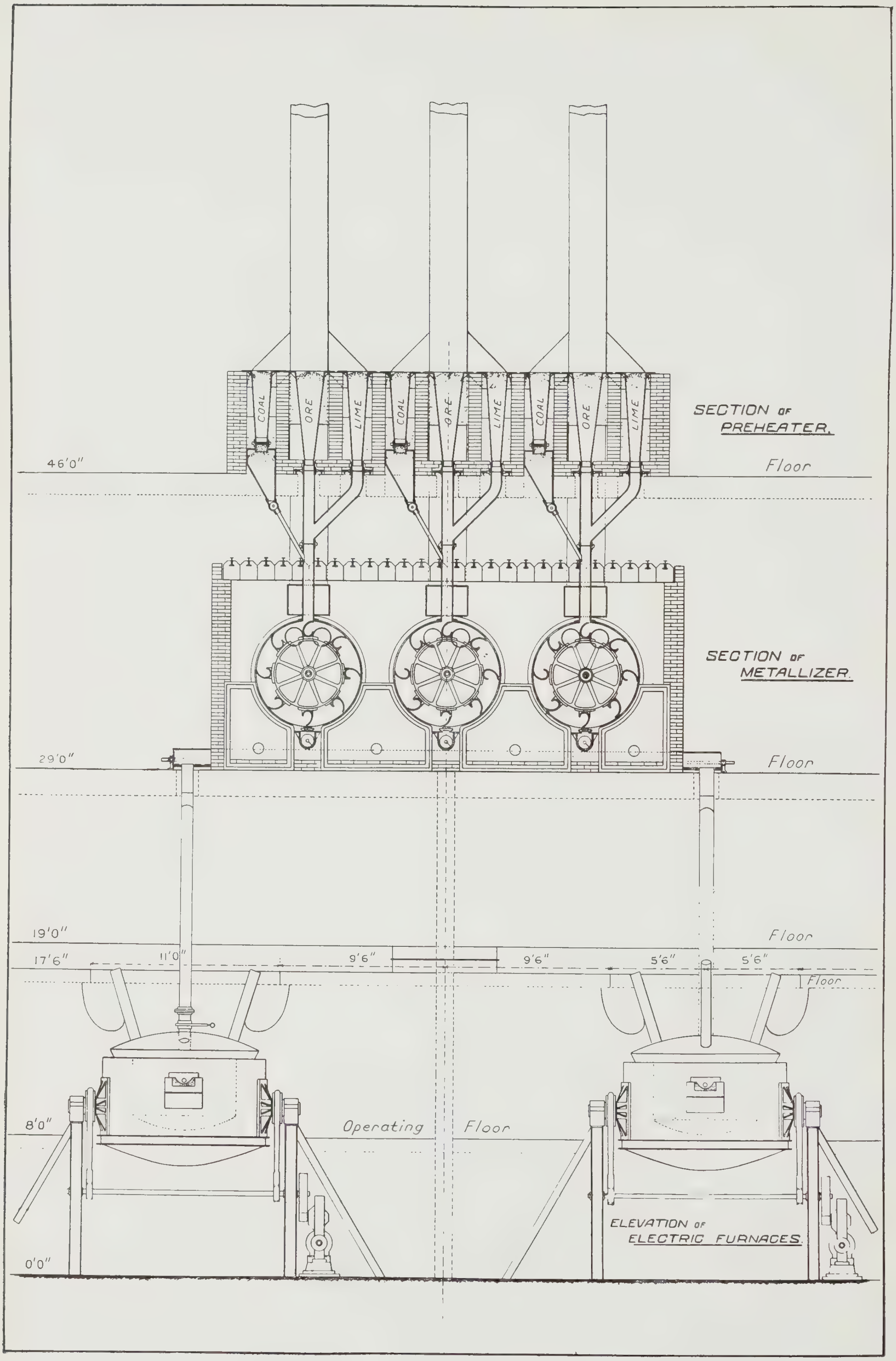


Fig. 19—Drawing showing preheater, metallizer, and electric furnace for use in Moffat sponge process.

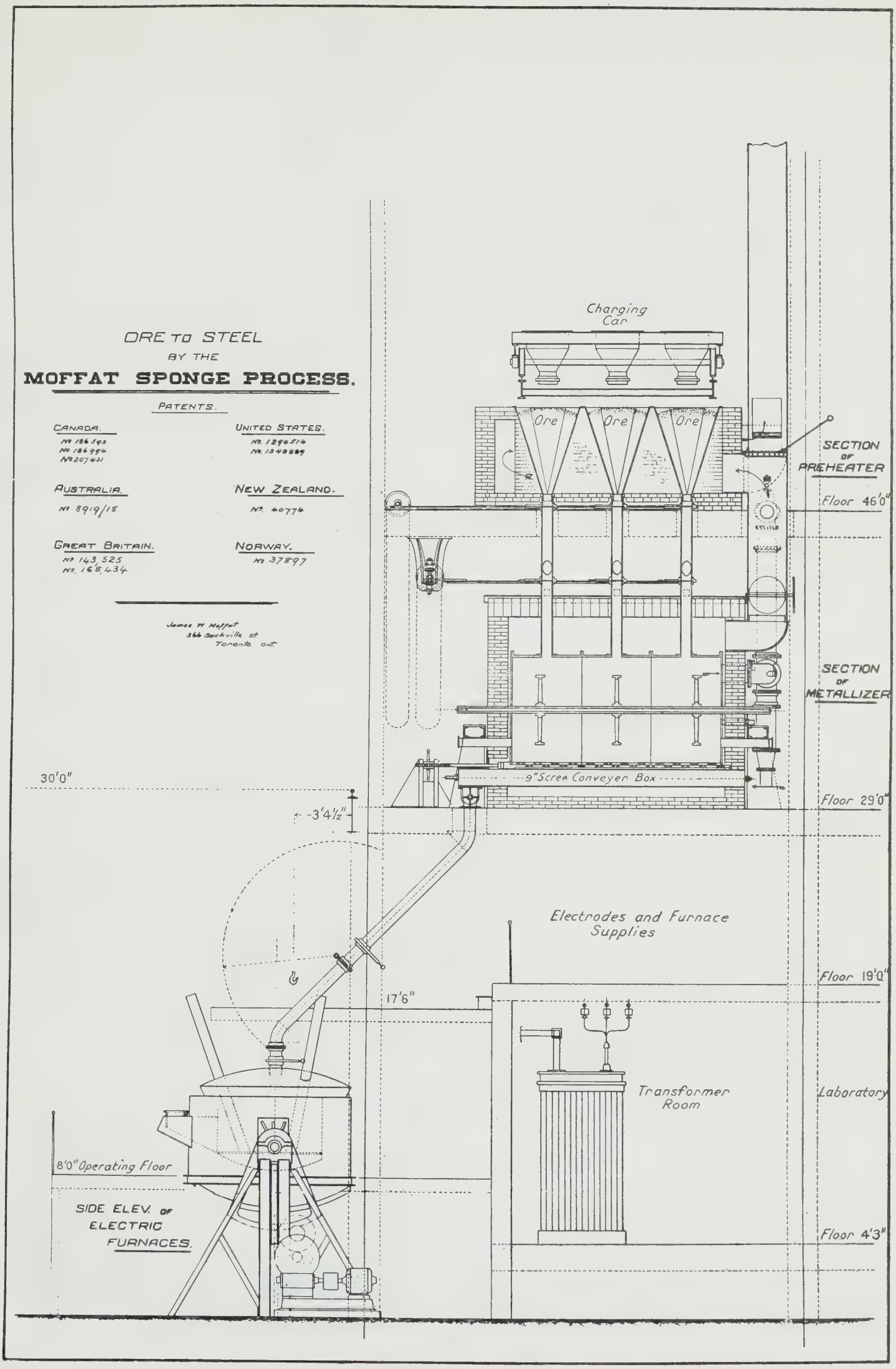


Fig. 20—Drawing showing preheater, metallizer, and electric furnace for use in Moffat sponge process.

by carbonaceous fuel and CO gas at a comparatively low temperature. The iron is not fused, but is in the form of a fine powder. It may be subsequently melted in an electric or other furnace.

Considerable work has been carried on by the United States Bureau of Mines at their experimental station in Seattle, under the superintendence of Clyde E. Williams. After much preliminary experimenting, their operations are now carried out in a kiln, 12 feet long. Both magnetite and hematite ores respond to the treatment. In all their experiments they have found that 100 per cent. of coal to ore is necessary. That is, one ton of ore would require one ton of coal. This would mean that with an ore containing a high-grade magnetite, about 1.7 tons of coal would be required to produce a ton of sponge iron. Obviously, such metallizing processes are not of much interest to us in Ontario.

In an attempt to relieve the electric furnace of the work of reduction and thus to lessen the power consumption, James W. Moffat, of Toronto, has worked out a process based largely on his experience with the Moffat-Irving furnace. He reduces finely-divided iron ore with fine coal in an externally heated drum in which the material is alternately lifted and dropped. When the charge in the drum is reduced, it is discharged, while still hot, into an electric furnace, where it is made into steel. He claims for a ton of steel a consumption of less than 0.4 tons of coal, and from 675 to 800 horsepower hours, or 500 to 600 kilowatt hours of electric energy. This would be a greatly diminished consumption over that necessary in present electric furnace practice working with ores. Mr. Moffat would require a high-grade iron ore, and when such is made available in Ontario his process may be considered in competition with the blast furnace and open hearth processes. Since beneficiated iron ores are often much purer than natural ores, their treatment in some such way would probably produce a much cleaner steel, which for a limited tonnage might command a much higher price in the market.

The proposed Moffat furnace is shown in Figs. 19 and 20.

Previous to the successful application of sintering, the problem of just what to do with a finely-divided magnetic concentrate presented some difficulty. No doubt many of the so-called metallizing processes, or direct processes, had their inception in this problem. This material would be suitable for such a process, and the blast furnace can not use such fine material. Since it has been demonstrated that fine concentrates may be sintered for a probable cost of 80 to 90 cents per ton, and thereby rendered ideal material for the blast furnace, it gives the metallizing process less ground for attracting attention. There have been many metallizing processes patented; they are known by name only. Commercial success has not been achieved so far in this field. Perhaps the most widely-known of these processes are the Bassett, the Bourcoud, and the Moffat. In connection with the metallurgy of copper, where iron may be used as a precipitant for copper from copper sulphate solutions, sponge iron is an ideal material, because it presents a maximum of surface. For this special purpose, its production has been successfully accomplished by the Chino Copper Company. Its production requires more fuel than does the blast furnace, and therefore it offers for us in Ontario no advantages whatever.

Direct Smelting of Ore in Electric Furnace

At the request of this committee, Dr. Alfred Stansfield has prepared a report on electric smelting of iron ore. (See Appendix, page 141.)

Direct smelting of ores in an electric furnace is an expensive operation. It might be warranted, at present, to the extent to which there is a demand for very high grade steel, in making which the electric furnace would use specially pure ores and charcoal instead of coke as a reducer.

An electric furnace has a small capacity per unit, and to make a uniform product great care must be exercised in operation. The fuel requirements, too, are considerable, and amount to between 0.35 and 0.4 tons of carbon per ton of product. The coke requirement in the blast furnace making basic iron will be between 0.9 and 1.0 tons of coke per ton of pig. The electric furnace requires ores high in iron. So limitations are seen in this direction, even if there should develop large-sized electric furnaces for such work.

The Estelle process for oxide ores uses the electric current and produces electrolytic iron with a very high consumption of electric energy per pound of iron produced. Each and every one of these processes requires a high-grade iron ore, the purer the better, and in the Estelle process, an extremely purified raw material. Now the whole question goes back again to the ores. Our Ontario ores are not high in iron: They require concentration. So competition between the blast furnace and other processes begins after there has been prepared a raw material suitable for either.

Ore Suitable for Special Processes Would be Suitable for Blast Furnaces

The point has been made with respect to our Ontario iron ores that since they are in their natural state unsuited to blast furnace treatment, they may be suited for some other iron-producing process. It has been suggested that we should not try to adapt our ores to existing blast furnace processes, but should adapt a process to our ores. There seems to be but one answer to this problem. There have been tried out a very great many processes other than the blast furnace for treating iron ores, but we have failed to find any process that does not require a high-grade material, that is material high in iron; the purer the ore the better. In other words, any ore that would be suitable for any of these special processes that have been evolved would be acceptable for the blast furnace. The only exception to this statement lies in the possibility of the pyrrhotite ores being used as a source for the production of electrolytic iron by leaching methods; but the pyrrhotite ores are not at the present time included among what we are accustomed to consider as iron ores. The problem is confined, therefore, to the production by beneficiation of suitable iron ore. This beneficiation may be magnetic concentration followed by sintering, which treatment would characterize deposits similar to those of Moose Mountain; or crushing and sintering, which treatment would characterize such deposits as the Atikokan, Helen, and Coehill.

Blast Furnace Process Best for Ontario

We are possessed of blast furnaces sufficient, probably, for all our present requirements. These furnaces have to compete in their product with the product which may be imported. Likewise, Ontario iron ores when prepared by beneficiation for the blast furnace will have to compete with the American ore. It would be an artificial situation, indeed, if this were not so. Other things being equal, the Ontario furnaces could be expected to give the preference to Ontario ores.

The logical development of an iron ore industry in Ontario lies in the direction of beneficiation of our Moose Mountain and Helen ores. These ore bodies are developed, and a very small gap remains to be bridged between the ore and the furnace. It is in this direction, utilizing the furnaces which we have, that the hope of the industry lies.

The successful development of any iron property in Ontario will be an incentive to similar development of other properties. But as long as we have a non-operating Moose Mountain in Ontario, or a shut-down Helen and Magpie, it is foolish to hope for capital to come into the province to develop similar ore bodies.

CHAPTER XI

CALCULATING THE VALUE OF IRON ORES

Items Affecting Valuation of Ores

The value of an ore is dependent upon its richness in iron, its composition, and its location, as well as its physical condition. It is impossible to consider any one of these qualifications entirely apart from the others. For instance a very lean ore, one low in iron, may have considerable value due to the self-fluxing character of its gangue and the consequent low cost of smelting. On the other hand, a rich ore may have associated with the iron, elements so deleterious in effect upon the pig iron as to render it valueless, owing to the cost of removing the impurities before smelting.

In general, ores profitable to smelt will contain from as low as 30 per cent. to as high as 60 or 65 per cent. metallic iron. In valuation each per cent. is termed a unit: Thus an ore with 50 per cent. metallic iron will have 50 units. It is evident that since iron is the constituent of value in any given ore, it must be in such quantity as to bear not only the cost of the ore laid down at the furnace, but the cost of its extraction, with profit. Furthermore, as the cost of reduction and melting any given quantity of iron as such is constant, the variable enters in the disposition of the gangue.

From this it will be seen that the value of an ore increases not only in proportion to the increase in the number of units of iron, but also and to an even greater extent, in proportion to the decrease in the quantity of gangue to be handled.

The gangue of iron ore consists principally of silica and alumina, together with small quantities of lime, magnesia, and oxides of manganese and the alkalies, as well as more or less phosphorus and sulphur. So far as the quality of the pig iron produced is concerned, all the above elements are more or less controlled by the burdening and operation of the furnace.

The sulphur, however, is only partly under control and requires for its even partial removal in the furnace, additional flux and fuel. Although no exact percentage can be given, as this is dependent on the analysis of the particular ore, the furnace operation, etc., any ore having more than 0.50 to 0.75 per cent. sulphur must be treated to remove a portion of this before being charged. Such added cost, together with the added expense of its smelting, will then determine whether or not the ore is suitable for making pig iron, even of such specifications as allow comparatively high sulphur. It might still be used in a mix with low sulphur ore.

Manganese is another element that is but partially under control. It is not harmful to pig iron within the limits of, say, 1 per cent. for Bessemer iron and $2\frac{1}{2}$ per cent. for the open hearth. On the average, about three-fourths

of the manganese in the ore will be reduced. However, if the percentage of manganese is sufficiently high as to be, say, 18 to 20 per cent., or over, in the pig, the ore is then suitable for the manufacture of standard ferro-manganese.

In phosphorus we have, more than in any other element, the controlling factor determining whether an ore is suitable from the standpoint of composition. It must be assumed that practically all the phosphorus in the ore goes into the iron, as very little, if any, can be eliminated in the blast furnace. The percentage of phosphorus leads to the two general divisions of Bessemer and non-Bessemer ores.

The location of ore bodies is naturally a most important consideration. Their location as regards fuel supply, means of transportation, and distance from the market, are among the determining factors. The size of the deposits will determine whether there is justification for the erection of a plant, although the wisdom of such an outlay will depend, in turn, wholly on the location of the present or future market for the output of the plant.

The whole question of ore treatment by whatever means is most vital, and on its development depends, in a great measure, the practically unlimited iron production of this country. Vast quantities of low-grade ore in the Superior region, until recently considered too highly siliceous to be of value, now bid fair to be large factors, due to processes of concentration recently perfected.

Although estimates of what may be the quantity of the ore bodies comprising the available supply must widely differ, due to the varied assumptions made and the many determinate factors, the ultimate exhaustion of the known rich ore bodies within a comparatively definite period seems assured. Nevertheless, such progress has been, and is being, made in methods of concentration as to ensure the availability of vast bodies of lean and impure ores and to place the date of their exhaustion far in the indefinite future.

Calculating the Value of Iron Ores from Analysis

For a good many years the value of the Lake Superior iron ores was arrived at by adding the freight rate from Lake Erie to the Valley furnaces to the price quoted per ton at Lake Erie on base ores, Old Range or Mesabi, and dividing this sum by the percentage of natural iron of such base ores. This gave a base unit value for figuring the price of all other standard Old Range and Mesabi ores. By multiplying the natural iron in any particular ore by the base unit value of either Old Range or Mesabi ores, as the case may be, and deducting from the result the freight rate previously added, the selling price of such ore at Lake Erie ports was obtained. Iron ore is mined, sold, transported, taxed, and the royalty is paid, on the basis of 2,240 pounds to the ton.

In the case of Bessemer ores, an addition or subtraction was made to provide for the percentage of phosphorus over or under the percentage of phosphorus in the base ore. At the present time, and for several years past, this deduction has been made according to a table of phosphorus values which has been established.

In 1908, the percentage of the base ore, both Old Range and Mesabi, was reduced to more nearly conform to the average percentage of iron in the ores being brought down from the upper lakes. This change was thought to be more

just to the furnace interests than by using the base percentage which had been established some years earlier when the average yield of all ores shipped from the Lake Superior region was higher. The present percentage in iron natural and phosphorus dry of the base ores, are as follows:—

A. Old Range Bessemer ores, 55 per cent. iron natural and 0.045 per cent. phosphorus, dried at 212° F.

B. Old Range non-Bessemer ores, 51.50 per cent. iron natural.

C. Mesabi Bessemer ores, 55 per cent. iron natural and 0.045 per cent. phosphorus, dried at 212° F.

D. Mesabi non-Bessemer ores, 51.50 per cent. iron natural.

To arrive at the base unit value, add 60 cents (an average freight rate to Valley furnaces on ores shipped from Lake Erie ports) to the base prices and divide this sum by the base natural iron.

The following example will illustrate this point:—

Assume the selling price of Class A ore to be	$6.45
Add average freight rate	.60
	$7.05
Then the base unit value is this sum divided by the base natural iron, or	$0.12818

Assuming the selling prices of classes A, B, C, and D to be $6.45, $5.70, $6.20, and $5.55 per ton, respectively, and figuring the values as above, the base unit values are found to be:—

For Old Range Bessemer ores	$0.12818
For Old Range non-Bessemer ores	0.12233
For Mesabi Bessemer ores	0.12364
For Mesabi non-Bessemer ores	0.11942

These base unit values are used to determine the premiums or penalties to be added to or subtracted from the quoted selling prices of the base ores, in order to arrive at the actual value of the ores which may contain more or less than the guaranteed percentages of natural iron of the base ores.

To figure the value of Bessemer ores, the following tables are used. For ores analyzing under 55 per cent. iron natural:—

From 55 to 50 per cent. iron natural, the value of each unit is the base unit.
From 50 to 49 per cent. iron natural, the value is the base unit, increase 50 per cent.
From 49 to 48 per cent. iron natural, the value is the base unit, increased 100 per cent.
Less than 48 per cent. iron natural, the value of each unit is 28 cents, or whatever figure is named in the ore contract.

For ores analyzing above 55 per cent. iron natural:—

From 55 to 56 per cent. iron natural, the value is the base unit increased 1 cent.
From 56 to 57 per cent. iron natural, the value is the base unit increased 2 cents.
From 57 to 58 per cent. iron natural, the value is the base unit increased 3 cents.
From 58 to 59 per cent. iron natural, the value is the base unit increased 4 cents.
From 59 to 60 per cent. iron natural, the value is the base unit increased 5 cents.
Over 60 per cent. iron natural, the value of each unit is the base unit value, or whatever figure is named in the contract.

To figure the value of non-Bessemer ores the following table is used:—

Above 50 per cent. iron natural, the value is the base unit.
From 50 to 49 per cent. iron natural, the value is the base unit plus 50 per cent.
From 49 to 48 per cent. iron natural, the value is the base unit plus 100 per cent.
Less than 48 per cent. iron natural, the value of each unit is 28 cents, or whatever figure is named in the ore contract.

The phosphorus adjustment is made according to the phosphorus table below:—

PHOSPHORUS TABLE

Percentage of phosphorus	Rate of progression	Phosphorus values	Percentage of phosphorus	Rate of progression	Phosphorus values
0.070	0.0200	0.3500	0.037	0.0115	0.0780
0.069	0.0195	0.3300	0.036	0.0120	0.0900
0.068	0.0190	0.3105	0.035	0.0125	0.1025
0.067	0.0185	0.2915	0.034	0.0130	0.1155
0.066	0.0180	0.2730	0.033	0.0135	0.1290
0.065	0.0175	0.2550	0.032	0.0140	0.1430
0.064	0.0170	0.2375	0.031	0.0145	0.1575
0.063	0.0165	0.2205	0.030	0.0150	0.1725
0.062	0.0160	0.2040	0.029	0.0155	0.1880
0.061	0.0155	0.1880	0.028	0.0160	0.2040
0.060	0.0150	0.1725	0.027	0.0165	0.2205
0.059	0.0145	0.1575	0.026	0.0170	0.2375
0.058	0.0140	0.1430	0.025	0.0175	0.2550
0.057	0.0135	0.1290	0.024	0.0180	0.2730
0.056	0.0130	0.1155	0.023	0.0185	0.2915
0.055	0.0125	0.1025	0.022	0.0190	0.3105
0.054	0.0120	0.0900	0.021	0.0195	0.3300
0.053	0.0115	0.0780	0.020	0.0200	0.3500
0.052	0.0110	0.0665	0.019	0.0205	0.3705
0.051	0.0105	0.0555	0.018	0.0210	0.3915
0.050	0.0100	0.0450	0.017	0.0215	0.4130
0.049	0.0095	0.0350	0.016	0.0220	0.4350
0.048	0.0090	0.0255	0.015	0.0225	0.4575
0.047	0.0085	0.0165	0.014	0.0230	0.4805
0.046	0.0080	0.0080	0.013	0.0235	0.5040
0.045	0.0000	0.0000	0.012	0.0240	0.5280
0.044	0.0080	0.0080	0.011	0.0245	0.5525
0.043	0.0085	0.0165	0.010	0.0250	0.5775
0.042	0.0090	0.0255	0.009	0.0255	0.6030
0.041	0.0095	0.0350	0.008	0.0260	0.6290
0.040	0.0100	0.0450	0.007	0.0265	0.6555
0.039	0.0105	0.0555	0.006	0.0270	0.6825
0.038	0.0110	0.0665	0.005	0.0275	0.7100

Until 1872, there was practically no difference in the prices of Bessemer and non-Bessemer ores, although in some instances non-Bessemer sold for more than Bessemer. Since 1872, Bessemer ores have commanded a better price than non-Bessemer ores. The difference between these two grades fluctuated from 80 cents in 1908, 1909, 1910, and 1913, to 75 cents in 1912, 1914, and thereafter to date (1923). This differential is not so great as indicated, however, as the two grades are sold under different guarantees. The base unit for Bessemer ores was introduced about 1897, and the guarantee was 56.70 per cent. iron, natural. No guarantee was given on non-Bessemer ores until 1899, when it was fixed at 54.36 per cent. iron, natural. In 1905 and 1906, the base unit for Mesabi non-Bessemer was 53.00 per cent. In 1907, base ores decreased from 56.70 to 55.00 for Bessemer, and from 52.80 to 51.50 for non-Bessemer ores.

To illustrate these calculations: Assume that the analysis of an Old Range Bessemer ore is 48 per cent. iron natural and 0.048 per cent. phosphorus, dried at 212° F., and that the base ore which is guaranteed to contain 55 per cent. iron natural and 0.045 per cent. phosphorus, dried at 212° F., is selling at $6.45 per ton, delivered at Lake Erie ports. The actual selling price would be calculated as follows:—

From 55 to 50 per cent. equals 5 units; 5 times the base unit equals	$0.64090
From 50 to 49 per cent. equals 1 unit; 1 times the base unit plus 50 per cent. equals	0.19227
From 49 to 48 per cent. equals 1 unit; 1 times the base unit plus 100 per cent. equals	0.25636
Penalty for iron	$1.08953
Penalty for phosphorus (from table)	.02550
Total penalty	$1.11503

or, in round figures, $1.12 per ton.

This penalty subtracted from the base price of $6.45 gives $5.33 as the actual selling price of the ore.

Suppose that the analysis of a Mesabi Bessemer ore is 57.50 per cent. iron natural and 0.043 per cent. phosphorus, dried at 212° F., and that the base ore which is guaranteed to contain 55 per cent. iron natural and 0.045 per cent. phosphorus, dried at 212° F., is selling at $6.20 per ton. Then the actual selling price would be calculated as follows:—

From 55 to 56 per cent. equals 1 unit; 1 times base unit plus 1 cent equals	$0.13364
From 56 to 57 per cent. equals 1 unit; 1 times base unit plus 2 cents equals	0.14364
From 57 to 57.50 per cent. equals 1/2 unit; one-half the base unit plus 3 cents equals	0.07682
Premium for iron	$0.35410
Premium for phosphorus (from table)	0.01650
Total premium	$0.37060

or, in round figures, $0.37 per ton.

This premium added to the base price of $6.20 gives $6.57 as the actual selling price of the ore.

Suppose that the analysis of an Old Range non-Bessemer ore is 48 per cent. iron natural and that the base ore which is guaranteed to contain 51.50 per cent. iron natural is selling for $5.70 per ton, delivered at Lake Erie ports. The actual selling price would be calculated as follows:—

From 51.50 to 50 per cent. equals 1 1/2 units; 1 1/2 times base unit equals	$0.18349
From 50 to 49 per cent. equals 1 unit; 1 times base unit plus 50 per cent. equals	0.18349
From 49 to 48 per cent. equals 1 unit; 1 times base unit plus 100 per cent. equals	0.24466
Total penalty	$0.61164

or, in round figures, $0.61 per ton.

This penalty subtracted from the base price, $5.70 per ton, gives $5.09 as the actual selling price of the ore.

Suppose that the analysis of a Mesabi non-Bessemer ore is 55 per cent. iron natural and that the base ore which is guaranteed to contain 51.50 per cent. iron natural is selling for $5.55 per ton, delivered at Lake Erie ports. The actual selling price would be calculated as follows:—

From 51.50 to 55 per cent. equals 3 1/2 units; 3 1/2 times base unit equals $0.41797

This would be the total premium, that is $0.42 per ton.

This premium added to the base price of $5.55 gives $5.97 as the actual selling price of the ore.

In a manganiferous ore, up to 4 or 5 per cent., the manganese is usually calculated as a metal with the iron; that is, the total percentage of iron and manganese in the natural, is used as a percentage of iron in calculating the value of the ore. For ores with a higher percentage of manganese than 4 or 5 per cent., a special price is generally made.

Siliceous ores, that is, ores containing 20 per cent. or more silica, are generally sold for a special price.

The market prices of Lake Superior iron ores at Lower Lake ports, for the years 1900 to 1923, are given in the Appendix on page 118.

CHAPTER XII

DESCRIPTION OF FURNACE RUNS ON MOOSE MOUNTAIN BRIQUETTES

Furnace tests were made on Moose Mountain briquettes at the works of the Steel Company of Canada, Hamilton, in October, 1922, and in April and May, 1923. In these tests approximately 10,000 tons of the material were used.

The October test run was made in "A" furnace, an old and relatively small furnace. The later tests were made in "B" furnace, a modern-type furnace of large capacity.

Fig. 21 (*a*)—Stock-pile of Moose Mountain briquettes.

In the "A" furnace test run, for four days briquettes made up 10 per cent. of the ore mixture. Then the percentage was increased to twenty.

In the "B" furnace test, fifteen per cent. of briquettes was used for two weeks, and then for a month the furnace was run with twenty-five per cent. of briquettes on the burden.

The attempt to use briquettes on "A" furnace was discontinued after fourteen days, for reasons given in the report of that run. When the figures for that period are compared with another period immediately following, the use of briquettes apparently resulted in better production and decreased coke consumption. If, however, they are compared with later periods, the advantage is lost, and decidedly so if compared with the month of May, when "A" furnace averaged 302 tons a day, as against 293 tons a day during the test.

In drawing any conclusions from what happened on "A" furnace as compared with the subsequent results on "B" furnace, it is necessary to take into

consideration the relative size of the furnaces. The two factors which determine the resistance met by the blast are the height and compactness of the descending column of stock, from which it follows that if two furnaces of different heights (a difference of fifteen feet in this particular case) are filled with the same material, the resistance of the shorter stock column is considerably less, and may be too low for satisfactory operation. Another fact which might have some bearing on the same matter is that the material used on "A" furnace came direct from Sellwood, where it had been separated from all fines, while that used at "B" furnace had been in the stock-pile all winter and had weathered considerably, with the result that by the time it was loaded into cars and put into the furnace bins many of the briquettes were broken up into smaller pieces.

Fig. 21 (*b*)—Close view of Moose Mountain briquettes on stock-pile.

The only suitable comparative period obtainable on "B" furnace, since it was blown in last January, was the first half of April, when operating conditions were finally stabilizing themselves after several weeks of changing due to market and other conditions. This resulted in the tests being run when the furnace had just hit its stride, and again the results looked exceedingly favourable for the briquettes. However, since the 30th of May, when the briquettes were used up, the furnace has been on Lake ore and is working better than it has done at any previous time. The average tonnage for the first four days in June was 518 tons a day, as compared with 475 tons a day on 25 per cent. Moose Mountain. June 2nd is the record day to date, with a production of 534 tons of iron on 1,855 pounds of coke, which surpasses the former record of 511 tons of iron on 1,929 pounds of coke made during the test run. Further than this,

"B" furnace is working more smoothly than it has heretofore, and with a blast heat of 200 degrees hotter, which last is very desirable. The worst trouble experienced with big furnaces is in getting them to operate smoothly in the face of hard driving and high blast heats. This is due to the zone of fusion working up too high in the furnace and causing dirty walls, which in turn will cause the furnace to "hang" and work irregularly. The above condition could also be brought about through a too open stock column failing to hold the zone of fusion down. The principal objection to Moose Mountain briquettes arises from the size and shape of the briquettes.

Summary of Conclusions from Test Runs

1. From the data collected, a positive statement as to whether Moose Mountain briquettes were beneficial or detrimental in a blast furnace in comparison with Lake ores would be open to question.

2. From a standpoint of chemical composition Moose Mountain briquettes are superior to most natural ores for the following reasons: (a) The iron content is from seven to ten points higher than the majority of non-Bessemer ores, and this results in better blast furnace yields. (b) The phosphorus is thirty-five points below the Bessemer standard. This lowers the amount of phosphorus to be removed in the basic open hearth furnaces; but as there is at present practically no Canadian market for low phosphorus Bessemer pig iron, blast furnace operators cannot pay any premium for this advantage.

3. From a standpoint of reducibility in the blast furnace, no definite statement can be made, but the briquettes are apparently reduced as readily as Lake Superior ores.

4. From a standpoint of their size, shape, etc., they are not all that could be desired, for the following reasons: (a) The run on "A" furnace was brought to a close through furnace irregularities which apparently originated in a too open stock column, brought about by the size of the briquettes, 4 by 8 by 2 inches. (b) From the smooth working of "B" furnace in the last three or four days, the tendency of the pressure in "A" furnace to go up for a couple of hours at a time during the tests may have been due to the zone of fusion getting a little too high up, or possible channelling of the gases caused by segregation of the briquettes in the furnace.

5. It has been demonstrated that at least 25 per cent. of Moose Mountain briquettes can be used satisfactorily in a modern furnace.

A Brief Comparison of "A" and "B" Furnaces

	"A"		"B"	
	ft.	in.	ft.	in.
Overall height	72	9	90	0
Hearth diameter	11	0	16	6
Hearth height	8	5	9	4
Bosh diameter	16	1	20	4½
Number of tuyères		8		8
Stock line diameter	12	0	15	0
Cubic feet of volume	9,368		19,437	

The above figures give a general idea of the much larger structure of the new "B" furnace as compared with "A." This increase in size translated into rated production per twenty-four hours, amounts to about 200 tons, the two furnaces being rated at 250 and 450 tons respectively.

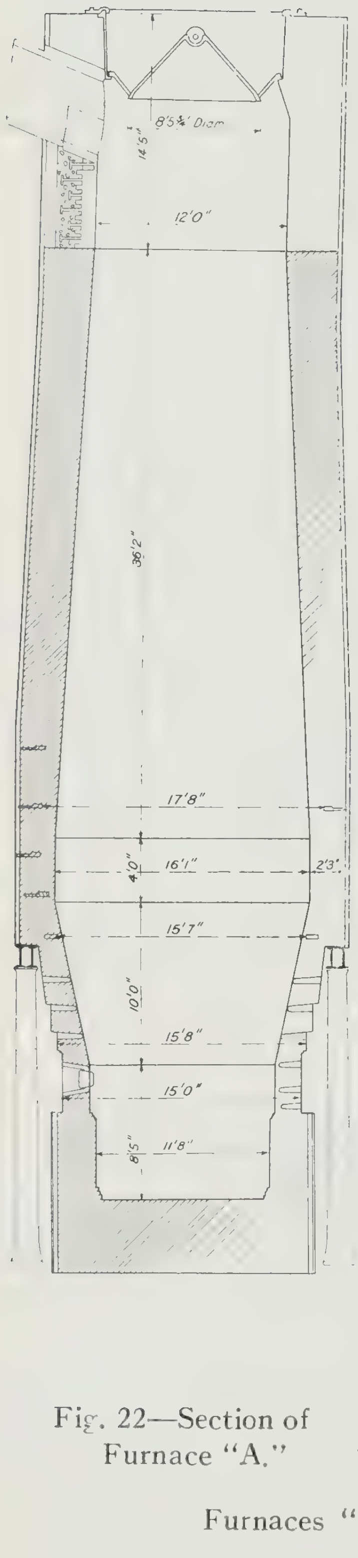


Fig. 22—Section of Furnace "A."

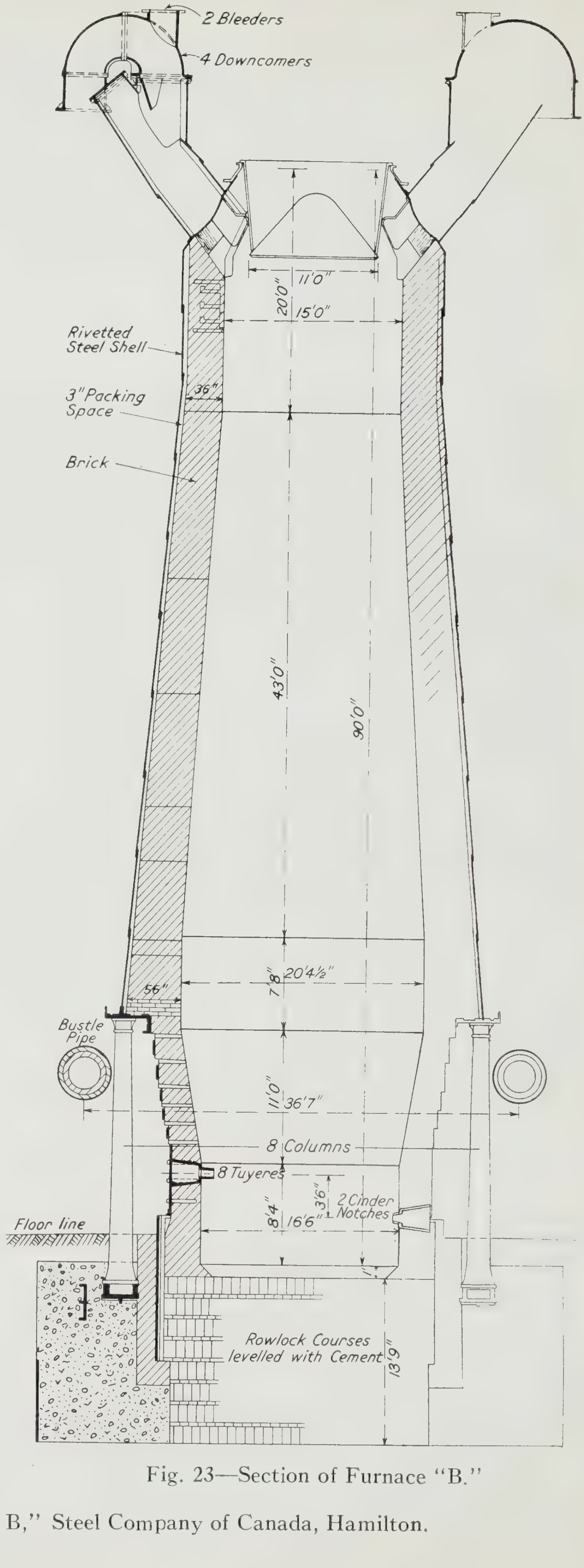


Fig. 23—Section of Furnace "B."

Furnaces "A" and "B," Steel Company of Canada, Hamilton.

As is shown in the furnace cross-sections, the general interior lines are the same for both furnaces, and this leaves but one important difference: the modern auxiliaries on "B" furnace.

The method used to close the furnace top is clearly seen in the cross-sectional reproductions. The cone-shaped section shown is called the bell. "A" furnace is what is known as a hand-filled furnace and has only one bell. The stock is loaded into buggies, placed on elevators, hoisted to the furnace top, and distributed around the circumference of this bell by hand. When the desired amount of material has been placed on the bell it is lowered and the stock slides into the furnace. In order to overcome the loss of gas when the bell is open, modern furnace tops are closed with two bells, one above the other, one closed when the other is open and vice versa.

Fig. 24—Moose Mountain briquettes: A piece of sinter and two small briquettes of other origin are shown for comparison. The scale is in inches.

Furnaces built in this fashion are equipped with automatic skip hoists, which means that all stock is dumped from the skip at a fixed point. To prevent the larger material from concentrating on the side of the furnace opposite this point, some form of distributor must be used. On "B" furnace this is taken care of by means of a McKee revolving distributor. This is in many ways the best furnace top available and, as may be seen from the accompanying photograph, is extremely simple. The stock is dumped from the skip into the receiving hopper marked "A", from whence it runs into the revolving hopper "B", which is closed at the bottom by a small bell. The capacity of the revolving hopper is equal to one skip, and by means of metallic packing at "C" a gas tight point is maintained. The circumference of the circle is divided at six points, and a complete charge is dumped on each of these points, or at 60, 120, 180, 240, 300, and 360 degrees. The dumping of the small bell takes place after every skip, and the big bell after any desired number of skips, which varies with the practice in vogue at the particular furnace.

The revolving of the hopper, and the dumping of the bell, is entirely automatic, and when once set for a certain cycle of operation, it is only necessary to start the hoist engine and the rest follows.

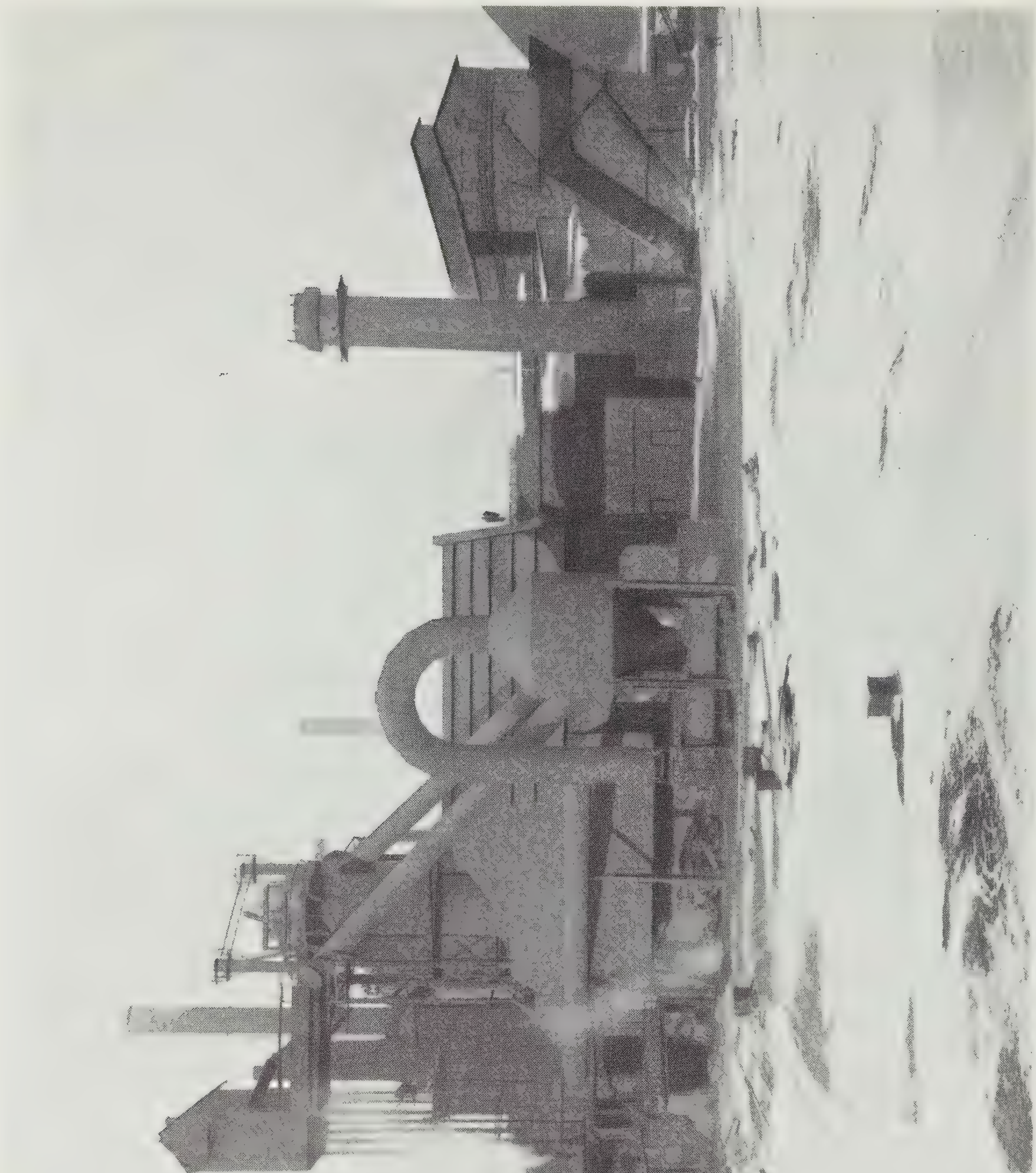


Fig. 25—"A" Furnace, Steel Company of Canada, Hamilton.

Report of Operations and Conclusions Following a Twelve Days' Run On 20 Per Cent. Moose Mountain Briquettes in "A" Furnace

Furnace "A", upon which this test was conducted, is a small furnace built in 1894, and while it lacks many of the modern features, such as skip hoists and revolving tops, its interior lines have been altered to conform with what is now considered to be the best practice.

On October 17th, 1922, 10 per cent. of Moose Mountain briquettes was placed on the burden. On the 20th this was increased to 20 per cent., at which figure it remained until the 29th. On the 28th the furnace began hanging and slipping, but settled down again until the 29th, when conditions grew so bad that it was considered advisable to discontinue the briquettes.

A blast furnace is said to hang when the stock column has failed to descend evenly as fusion takes place at the tuyères. The slip which follows the hanging is similar in action to the plunger in a pump, and very high pressure is momentarily generated in the lower part of the furnace. This results in stock being blown from the top or, in extreme cases, in old furnaces, the entire top may be blown off.

From the above it is easily understood that such a condition must be carefully avoided in an old furnace, as it not only makes good production impossible and threatens the furnace structure, but endangers the lives of those working round about.

Included in this report are reproductions of two charts taken from the gauge recording the blast pressure. One is a normal chart with the pressure uniform in the vicinity of twelve pounds; the other is a chart for the 29th of October. In comparing these charts it will be seen that the pressure dropped at three-hour intervals, corresponding roughly to the hours of two, five, eight, and eleven o'clock. These checks are normal and take place when casting the furnace. On the chart for the 29th the drops in pressure appearing between casts are due to the furnace being checked, or in other words, having the blast taken off, so that the stock column will settle down as it should. It will be seen from this chart that the furnace was working irregularly and under high pressure for nearly twelve hours.

In order to draw some sort of comparison between the actual furnace conditions, with and without the use of briquettes, it was necessary to select a period with the furnace on Lake ore, when all other conditions were as nearly uniform as possible. Owing to the furnace having only resumed operations on the 15th of September, after a prolonged period of inactivity, and owing to the fact that the fuel supply is at present varying from day to day, it was impossible to get exactly the same set of conditions, but the period selected is the best that could be done under the circumstances.

The chief points of difference are, that the test took place about a month after the furnace went in and at a time when it was doing the best work in its history, that the coke used was much better during October, and that excess scrap was charged all through the test period.

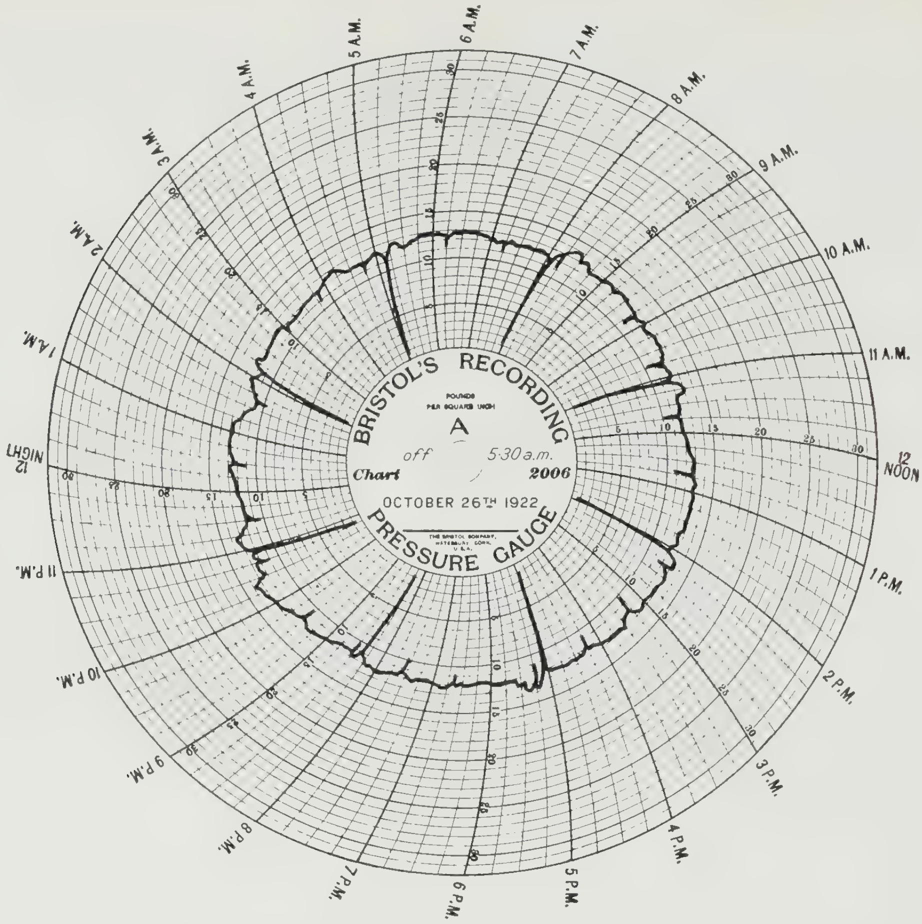


Fig. 26—Pressure chart, Furnace "A," October 26, 1922, showing record under normal conditions.

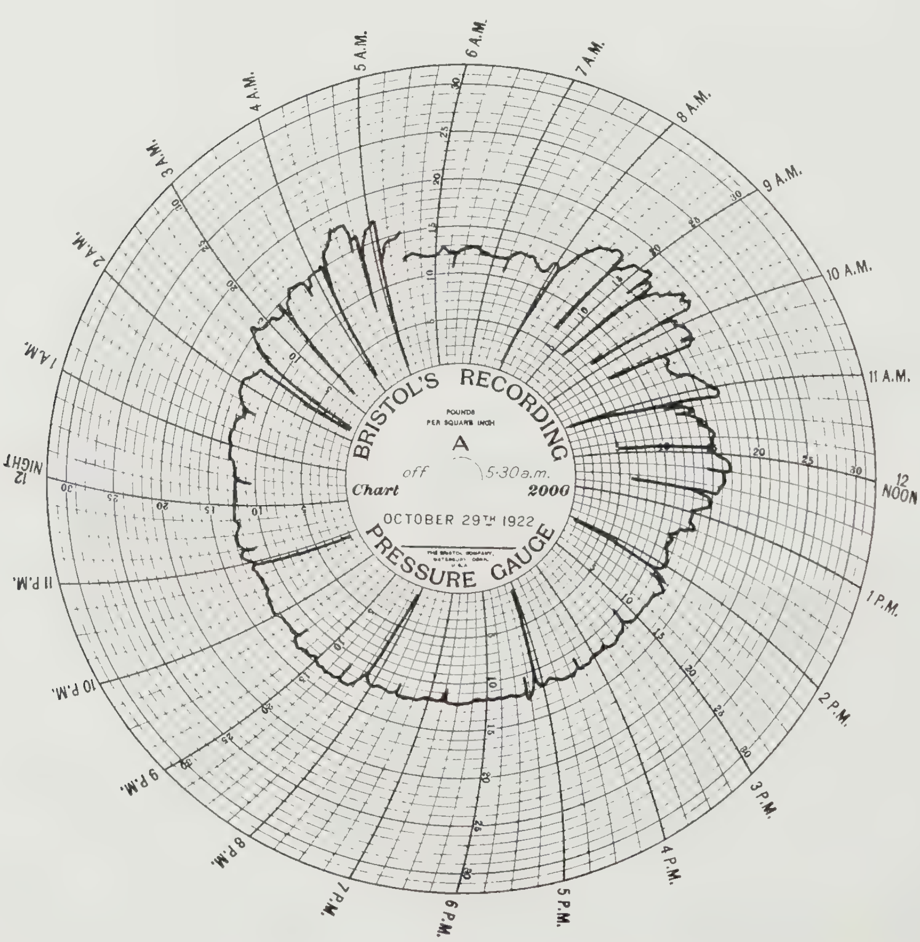


Fig. 27—Pressure chart, Furnace "A," October 29, 1922, showing record of irregular high pressures.

In connection with the fuel, the analyses given on the long daily practice sheet represents fresh coke coming from the ovens, which was mixed at the furnace with coke already in stock. This stock coke was of a much better grade and was used in the proportions shown below:—

	Per cent. stock	Per cent. fresh
TEST PERIOD		
October 17th to 28th, inclusive	46	54
COMPARATIVE PERIOD		
November 1st to 12th, inclusive:		
November 1	40	60
November 6	30	70
November 8	25	75
November 11	15	85
November 12	10	90
Average	27.7	72.3

The larger proportion of stock coke used during the test period gives that run a decided advantage.

The conclusions to be drawn from the results of the test as shown on the data sheets are as follows:—

1. From the standpoint of chemical constitution and reducibility there is no reason why a large percentage of Moose Mountain briquettes could not be used in place of Lake Superior ores.

2. The present physical characters, size, shape, etc., of the briquettes prohibit their use in any large proportions.

Present blast furnace efficiency is largely due to proper distribution of the material over the cross-section of the furnace. This proper distribution has been accomplished by a long series of cut and try experiments with the class of raw materials commonly used. Briquettes the size of a nine-inch brick are so radically different from ores commonly used that the entire distribution would be changed by them. When these briquettes are added to the charge, the centre is opened up. This results in too much gas passing up through the centre of the furnace and not enough up the walls. The results of this gas action are higher top heats, higher flue dust production, and ultimate sticking and hanging due to dirty walls. It will be noticed that the top heat and flue dust production were higher during the period the briquettes were used, and the hanging was encountered after twelve days. It might perhaps be mentioned that this was the only protracted period of hanging on the furnace since it was blown in.

Owing to the age of the comparatively thin plate in "A" furnace shell, the management has deemed it inadvisable to take any further unnecessary risks along the line of high pressure or slips on this furnace, and no further attempts to utilize Moose Mountain briquettes have been made in "A" furnace.

BURDEN SHEET

Date: October 17th to 28th, inclusive.
Mixture: Basic.
Furnace: "A"

STOCK			Fe	Phos.	Mn	SiO_2	Al_2O_3	CaO	MgO	S
			%	%	%	%	%	%	%	%
Plymouth			53.11	0.086	0.50	3.28	1.25	0.12	0.18	0.009
Danube			52.98	0.068	0.21	11.37	0.59	0.19	0.17	0.007
Cedar			48.92	0.125	0.23	7.88	4.25	0.99	2.11	0.019
Portsmouth-Rex			35.93	0.274	6.83	6.11	3.34	1.44	0.52	0.022
Moose Mountain			60.33	0.013	0.05	6.84	0.33	0.34	0.28	0.032
Scale			62.00	0.024	0.27	1.86	0.26	0.18	0.14	0.025
Scrap			90.00	......	......	......	......	......	......	......
Coke, direct			......	......	......	5.86	3.11	0.72	0.32	1.05
Coke, stock			......	......	......	4.55	2.39	0.65	0.32	0.75
Beachville stone			......	......	......	0.65	0.65	53.45	1.29	0.025
MIXTURE	tons	%								
Plymouth	1,766	28.5	15.13	0.024	0.14	0.93	0.36	0.03	0.05	......
Danube	1,177	19.0	10.06	0.013	0.04	2.16	0.11	0.04	0.03	......
Cedar	955	15.5	7.58	0.019	0.03	1.22	0.66	0.15	0.33	......
Portsmouth-Rex	923	15.0	5.39	0.041	1.02	0.92	0.50	0.22	0.08	......
Moose Mountain	1,032	17.0	10.25	0.002	......	1.16	0.06	0.06	0.05	......
Scale	308	5.0	3.10	0.001	0.01	0.09	0.01	......	......	......
Average ore	6,161	100.0	51.51	0.100	1.24	6.48	1.70	0.50	0.54	......
WEIGHT OF CHARGE		tons	tons	tons	tons	tons	tons	tons	tons	tons
Ore		6,161	3,173	6.16	76.40	399.23	104.74	30.80	33.27	......
Coke, direct		1,659	......	......	......	97.22	51.49	11.94	5.31	17.42
Coke, stock		1,413	......	......	......	64.29	33.77	9.18	4.52	10.60
Stone		1,047	......	......	......	6.80	6.80	559.62	13.50	......
Scrap		308	277	......	......	......	......	......	......	......
Total charge		......	3,450	6.16	76.40	567.54	196.80	611.54	56.60	28.02

		tons	
SILICA IN CHARGE		567.54	
SiO_2 to provide 1.17 per cent. Si in pig		92.00	% Theoretical
SLAG	SiO_2	475.54	34.72
	Al_2O_3	196.80	14.40
	CaO	611.54	44.66
	MgO	56.60	4.17
	S	28.02	2.05
POUNDS SLAG PER TON PIG IRON, 871.	Total slag	1,368.50	100.00

		%
IRON: 3,675 tons.	Yield	56.80
	Phosphorus	0.168
	Manganese	1.56
	Silicon	1.17

REMARKS.—The analyses given at the top of this sheet are average analyses; in the case of ore, the average for last season's deliveries. In blast furnace calculations, on Lake ore the sulphur is low enough to be disregarded; with phosphorus, anything beyond the third decimal place is disregarded; on all other elements, anything beyond two places of decimals. By "tons" is meant gross tons throughout.

BURDEN SHEET

Date: November 1st to 12th, 1922, inclusive.
Mixture: Basic.
Furnace: "A".

STOCK	Fe	Phos.	Mn	SiO_2	Al_2O_3	CaO	MgO	S
	%	%	%	%	%	%	%	%
Plymouth	53.11	0.086	0.50	3.28	1.25	0.12	0.18	0.009
Danube	52.98	0.068	0.21	11.37	0.59	0.19	0.17	0.007
Cedar	48.92	0.125	0.23	7.88	4.25	0.99	2.11	0.019
Portsmouth-Rex	35.93	0.274	6.83	6.11	3.34	1.44	0.52	0.022
Moose Mountain	60.33	0.013	0.05	6.84	0.33	0.34	0.28	0.032
Osana	50.39	0.470	0.30	6.23	3.33	1.36	1.47	0.027
Richmond	39.69	0.043	0.11	37.33	0.99	0.42	0.36	0.001
Scale	62.00	0.043	0.27	1.86	0.26	0.18	0.14	0.025
Scrap	90.00	......	......	......	......	......	......	......
Coke, direct	......	......	......	5.86	3.11	0.72	0.32	1.05
Coke, stock	......	......	......	4.55	2.39	0.65	0.32	0.75
Beachville	......	......	......	0.65	0.65	53.45	1.29	0.025

MIXTURE	tons	%	Fe	Phos.	Mn	SiO_2	Al_2O_3	CaO	MgO	S
Plymouth	1,623	27.0	14.33	0.023	0.13	0.88	0.34	0.03	0.05	......
Danube	1,879	31.5	16.69	0.021	0.07	3.58	0.18	0.06	0.05	......
Cedar	716	12.0	5.87	0.015	0.03	0.94	0.51	0.12	0.25	......
Portsmouth-Rex	895	15.0	5.39	0.041	1.02	0.92	0.50	0.22	0.08	......
Moose Mountain	60	1.0	0.60	......	......	0.07	......	......	......	......
Osana	477	8.0	4.03	0.038	0.02	0.50	0.27	0.11	0.12	......
Richmond	17	0.5	0.20	......	......	0.19	......	......	......	......
Scale	298	5.0	3.10	0.001	0.01	0.09	0.01	......	......	......
Average ore	5,965	100.0	50.21	0.139	1.28	7.17	1.81	0.54	0.55	......

WEIGHT OF CHARGE	tons	tons	tons	tons	tons	tons	tons	tons	tons
Ore	5,965	2,995	8.19	76.35	427.69	107.96	32.21	32.80	......
Coke, direct	1,938	......	......	......	113.57	60.27	13.95	6.20	20.35
Coke, stock	1,043	......	......	......	47.46	24.93	6.78	3.34	7.82
Stone	1,052	......	......	......	6.84	6.84	562.29	13.57	......
Scrap	244	219.6	......	......	......	......	......	......	......
Total charge	......	3,214.6	8.19	76.35	595.56	200.00	615.23	55.91	28.17

		tons	% Theoretical
SILICA IN CHARGE		595.56	
SiO_2 to provide 1.33 per cent. Si in pig		97.20	
SLAG	SiO_2	498.36	35.66
	Al_2O_3	200.00	14.31
	CaO	615.23	44.01
	MgO	55.91	4.01
	S	28.17	2.01
POUNDS SLAG PER TON PIG IRON: 915.	Total slag	1,397.67	100.00

IRON: 3,420 tons.

	%
Yield	55.05
Phosphorus	0.239
Manganese	1.67
Silicon	1.33

REMARKS.—The analyses given at the top of this sheet are average analyses; in the case of ore, the average for last season's deliveries. In blast furnace calculations, on Lake ore, the sulphur is low enough to be disregarded; with phosphorus, anything beyond the third decimal place is disregarded; with all other elements, anything beyond two places of decimals. By "tons" is meant gross tons throughout

BLAST FURNACE PRACTICE DATA

Furnace "A"

	Period of test, Oct. 17th to 28th, inclusive	Comparative period, Nov. 1st, to 12th, inclusive
Grade of iron	Basic	Basic
Time of operation.....days	12	12
Total product.....tons	3,519	3,274
Average daily production..... "	293.2	272.8
Production per 24 hours per 100 cu. ft. volume..... "	3.13	2.91
Total ore used.....tons	5,853	5,667
Total cinder used..... "	....	....
Total scale used..... "	308	298
Total excess scrap used..... "	308	244
Total coke used.....net tons	3,441	3,341
Total Beachville stone used.....tons	1,047	1,052
Total of all material used..... "	10,957	10,602
Ore mixture per ton iron.....lbs.	3,921	4,081
Scrap per ton iron..... "	195	167
Coke per ton iron..... "	1,955	2,039
Stone per ton iron..... "	666	719
All material per ton iron..... "	6,737	7,006
Silica in ore mixture.....per cent.	6.48	7.17
Average coke ash..... " "	9.95	10.53
Average coke sulphur..... " "	0.93	0.96
Burden ratio..... " "	2.11	2.09
Theoretical yield.....per cent.	56.80	55.05
Actual yield..... " "	54.40	52.60
Loss in yield..... " "	2.40	2.45
Flue dust produced.....tons	296	252
Flue dust per ton iron.....lbs.	188	172
Average air temperature.....degrees F.	46	48
Average grains moisture in air	2.34	2.87
Air per pound coke.....cu. ft.	53.5	54.9
Air per minute at 62° F..... " "	21,453	21,243
Blast temperature.....degrees F.	1,184	1,115
Top temperature..... " "	440	422
Average silicon in pig.....per cent.	1.17	1.33
Average sulphur in pig..... " "	0.039	0.041
Average phosphorus in pig..... " "	0.19	0.25
Average manganese in pig..... " "	1.85	1.75
Per cent. off sulphur iron..... " "	1.04	5.20
Average silica in slag.....per cent.	36.79	37.12
Average alumina in slag..... " "	15.18	16.45
Average sulphur in slag..... " "	1.92	2.00
Total time lost.....minutes	138	171

Furnace "A," blown in Sept. 15th, 1922.

TEST RUN, OCT. 17TH TO 28TH, 1922, INCLUSIVE

Date	Mixture: Plymouth	Mixture: Danube	Mixture: Osana	Mixture: Cedar	Mixture: Portsmouth-Rex	Mixture: Richmond	Mixture: Moose Mountain	Mixture: Scale	Burden: Ore	Burden: Coke	Burden: Stone	Burden: Scrap	SiO_2 in mixture	Fuel ratio	Charges	Extra coke	Blast: Cu. ft. per min.: Actual	Blast: Cu. ft. per min.: Equivalent at 62° F.	Blast: Pressure	Blast: Temperature	Blast: Cu. ft. air per lb. coke	Blast: Gr. moisture per cu. ft.
	%	%	%	%	%	%	%	%	lbs	lbs	lbs.	lbs.	%	%						° F.		
17	27 5	22 5		20 0	15		10	5	10,000	4 800	1,700	500	6 65	2 18	112	.	20,800	21,420	12 0	1,170	55 3	2 18
18	32 5	"		15 0	"		"	"	"	"	"	"	"	2 17	118	4	20,800	21,670	12 0	1,150	51 0	1 82
19	"	"		"	"		"	"	"	"	"	"	"	2 17	115	4	20,860	21,610	12 2	1,150	53.6	1 91
20	27 5	17 5		"	"		20	"	"	"	"	"	6 30	2 18	116	.	20,760	21,790	12 0	1,175	53 0	1.67
21	"	"		"	"		"	"	"	"	"	"	"	2 18	116	.	20,720	21,280	12.0	1,175	53 1	3 11
22	"	"		"	"		"	"	"	"	"	"	"	2 17	113	4	20,720	20,800	12 0	1,230	54 1	3.78
23	"	"	....	"	"	......	"	"	"	"	"	"	"	2.17	113	4	20,830	21,540	12.2	1,180	54.3	2.30
24	"	"	....	"	"	......	"	"	"	"	"	"	"	2.17	115	4	20,870	21,390	12.5	1,175	53.5	2.45
25	"	"		"	"		"	"	"	"	"	"	"	2.18	112	.	20,900	21,420	12.5	1,200	55.5	2.55
26	"	"		"	"		"	"	"	"	"	"	"	2.17	117	4	20,800	21,590	12.7	1,200	52.5	2 03
27	"	"		"	"		"	"	"	"	"	"	"	2.18	117	.	20,870	21,530	13.0	1,180	53.2	2.17
28	"	"		"	"		"	"	"	"	"	"	"	2 17	115	4	20,530	21,430	13.5	1,225	52 7	2 07
Av	28 5	19 0		15 5	15		17	5	10,000	*4 970	1,700	500	*6 48	*2 11	115	.	20,788	*21,453	12 4	1,184	53 5	2 34

Date	Grade	Product: Daily tonnage	Product: Average per period	Product: Analysis: Silicon	Product: Analysis: Sulphur	Product: Analysis: Phosphorus	Product: Analysis: Manganese	Product: Per cent off	Slag: SiO_2	Slag: Al_2O_3	Slag: Sulphur	Coke: Daily	Coke: Period	Stone per ton	Top heat	Yield: Theoretical	Yield: Actual	Yield: Difference	Coke: Analysis: Moisture	Coke: Analysis: Ash	Coke: Analysis: Sulphur	Coke: Coal mix.: Mather	Coke: Coal mix.: Pocy	Coke: Coal mix.: Hillman	Time
		tons	tons	%	%	%	%	%	%	%	%	tons	tons	tons	° F	%	%	%	%	%	%	%	%	%	hrs
17		287	287	1.27	0 043	0.22	1 77	12 5	37 74	15.70	1 89	1,874	1,874	663	475	55 62	55 57	0 05	1 87	10 68	1 08				24
18		281	284	1 30	0.042	0.20	1 68		36 40	15.40	1 82	2,032	1,923	713	480	"	51 20	4 42	1 87	10 32	1 08				"
19		289	286	1.23	0.039	0 19	1.53		37 80	14 80	1 80	1,926	1,943	674	465	"	54 10	1 52	1 87	10 42	1 09	85	15		"
20		290	287	1.21	0 040	0 20	1 79	.	36 80	15.50	1.86	1,920	1,939	680	485	57 77	53.76	1 86	1 87	10 58	1 07	"	"		"
21		295	288	1 21	0 038	0 19	1 88					1,887	1,927	667	440	"	54 80	2 97	1 87	11 26	1 06	"	"		"
22		298	290	1 07	0 039	0 18	1 80	.	36 60	15 30	1 93	1,836	1,911	644	430	"	56.70	1 07	1 87	10 46	1 07	"	"		"
23	Basic	291	290	1.16	0.041	0.19	1.85	......	37.04	15.00	1.96	1,880	1,906	660	425	"	55.40	2.37	1.87	10.42	1 07		"	85	"
24		293	290	1.02	0.038	0.19	2.00	......	36.40	14.88	2.00	1,900	1,905	667	440	"	54.77	3.00	1.87	10.64	1 09	85	"		"
25		284	290	1 16	0 037	0 20	1 98		36 20	15.08	1 94	1,891	1,904	676	440	"	54 50	3 27	2 19	11.06	1 09	"	"		"
26		305	291	1 09	0 040	0 19	2 17		36 70	14 80	1 94	1,857	1,900	652	415	"	56 12	1 65	2 19	11 26	1 09	"	"		"
27		297	292	1 13	0 036	0 19	1.83	.	36 20	15 30	2 02	1,887	1,898	665	394	"	54 67	3 10	1 87	10 68	1 11	"	"		"
28		309	293	1.25	0 031	0 18	1 93		.	. .		1,804	1,890	636	395	"	57 80	0 03	1 87	11 44	1 08	"	"		"
Av			293	1 17	0 039	0 19	1 85	1 04	36 79	15 18	1 92		*1,955	666	440	*56 80	*54 40	*2 40	1 92	10 77	1 08				24

COMPARATIVE PERIOD, NOV. 1ST TO 12TH, INCLUSIVE

Date	Mixture: Plymouth	Mixture: Danube	Mixture: Osana	Mixture: Cedar	Mixture: Portsmouth-Rex	Mixture: Richmond	Mixture: Moose Mountain	Mixture: Scale	Burden: Ore	Burden: Coke	Burden: Stone	Burden: Scrap	SiO_2 in mixture	Fuel ratio	Charges	Extra coke	Blast: Cu. ft. per min.: Actual	Blast: Cu. ft. per min.: Equivalent at 62° F.	Blast: Pressure	Blast: Temperature	Blast: Cu. ft. air per lb. coke	Blast: Gr. moisture per cu. ft.
1	25 0	30 0		20 0	15		5	5	10,000	4,850	1,700	500	7 10	2 16	112		20,400	21,130	12.7	950	54 2	2.83
2	"	"	....	"	"	......	"	"	"	"	"	"	"	2.16	111	...	20,800	21,300	12.0	1,000	55.3	3.47
3	27 5	32 5	10	10 0	"			"	"	"	"	"	7 07	2 16	109		20,650	21,000	12.0	1,000	55.7	3 58
4	"	"	"	"	"	......	....	"	10,200	"	"	"	"	2.18	108	...	20,720	21,200	12.5	1,000	56.3	2.91
5	"	"	"	"	"			"	"	"	"	"	"	2 20	111		20,400	20.910	12 5	1,025	54 9	3 28
6	"	"	"	"	"			"	"	"	"	"	"	2 20	109		20,570	21,130	12.5	1,160	55 4	3 22
7	"	"	"	"	"			"	"	"	"	"	"	2.18	110	4	20,800	21,240	12.5	1,200	54.8	2.68
8	"	"	"	"	"			"	"	"	"	"	"	2.18	112	4	20,830	21,540	12 5	1,200	54 4	2 53
9	"	"	"	"	"		.	"	10,000	"	1,800	"	"	2.16	115	. .	20,650	21,600	12.5	1,200	53 0	1.89
10	"	"	"	"	"	......	......	"	"	"	"	"	"	2.15	115	...	20,790	21,450	12.5	1,200	53.4	2.64
11	27 5	30 0	"	"	"	2 5		"	9,800	"	2,000		7 72	2 02	108	4	20,790	21,040	13 0	1,260	55 3	3.42
12	"	"	"	"	"	"		"		"	"	"	"	2 02	110	.	20,830	21,620	12 5	1,180	55.7	1 99
Av	27 0	31 5	8	12 0	15	0 5	1	5	10,015	*5,015	1,773	410	*7 17	*2 09	111		20,686	*21,243	12 5	1,115	54 9	2 87

Date	Grade	Product: Daily tonnage	Product: Average per period	Product: Analysis: Silicon	Product: Analysis: Sulphur	Product: Analysis: Phosphorus	Product: Analysis: Manganese	Product: Per cent off	Slag: SiO_2	Slag: Al_2O_3	Slag: Sulphur	Coke: Daily	Coke: Period	Stone per ton	Top heat	Yield: Theoretical	Yield: Actual	Yield: Difference	Coke: Analysis: Moisture	Coke: Analysis: Ash	Coke: Analysis: Sulphur	Coke: Coal mix.: Mather	Coke: Coal mix.: Pocy	Coke: Coal mix.: Hillman	Time
1		283	283	1 42	0 037	0 20	1 56		37 20	17 40	2 08	1,919	1,919	672	420	56 60	54 37	2 2	1 87	11 86	1 10		20	80	24
2		280	281	1.34	0.037	0.22	1.67	......	37.94	15.70	2.04	1,923	1,921	674	406	"	53.90	2.7	1.87	11.66	1 08	80	"		"
3		263	276	1 47	0 039	0 22	1 74		37 40	16.00	2 04	2,010	1,947	704	442	"	51 53	5 1	2 19	11 40	1 02	"	"		"
4		274	275	1.44	0.034	0.24	1.81	......	......	......	......	1,912	1,940	670	408	"	53.75	2.8	1.87	11.02	1 12	"	"		"
5		282	276	1.19	0 039	0 24	1 70		37 00	15 90	2 04	1,909	1,933	669	412	"	53 21	3.4	2 19	10.92	1 07	"	"		"
6		280	277	1.16	0 042	0 25	1 85		38 28	15 74	2 12	1,888	1,926	662	391	"	53 76	2 8	1 87	11 04	1 06	"	"		"
7	Basic	271	277	1.54	0 043	0 25	1 97	25 0	37 00	20.00	1 96	1,987	1,935	720	403	"	51.62	5 0	1 87	11 16	1 07		"	80	"
8		277	277	1.12	0 046	0.27	1 97		36 80	16 60	1 96	1,978	1 940	728	427	"	51.87	4 7	2 19	11 30	1 09		"	"	"
9		279	277	1.21	0 047	0.27	1.83	37 0	36 80	16 00	1 90	1,999	1,946	742	422	56 00	51 76	4.2	1 87	11 62	1 10		"	"	"
10		285	277	1.17	0.042	0.28	1.64	......	37.16	16.00	1.96	1,957	1,947	726	443	"	53.37	2.6	1.87	11.08	1 03	80	"		"
11		246	274	1 21	0.052	0 27	1 50	37.0			.	2,149	1,964	823	414	53 35	49 68	3 7	1 87	11 68	1 06	"	"		"
12		254	273	1 65	0 030	0.26	1 72	.	35 60	15 20	1.90	2,100	1,974	866	477	"	52 71	0 6	1 87	11 44	1 10	"	"		"
Av			273	1 33	0 041	0 25	1 75	5 20	37 12	16 45	2 00		*2,039	719	422	*55 05	*52 60	*2 45	1 95	11 35	1 07				24

NOTE: The averages marked with a star will not check with the column above, for the daily furnace coke is measured by volume and a correction made at the end of a month to bring the daily figures to the railroad weights. The average volume of air at 62° F. is the average actual volume taken at the average temperature for the period. The yield figures are derived from computations based on the entire period, at its conclusion.

Moose Mountain Briquettes in "B" Furnace

On the following pages will be found the results obtained April 16th to April 29th, and April 30th to May 30th, 1923.

During the period April 16th to April 29th, the charge contained 15 per cent. briquettes.

During the period April 30th to May 30th, the charge contained 25 per cent. briquettes.

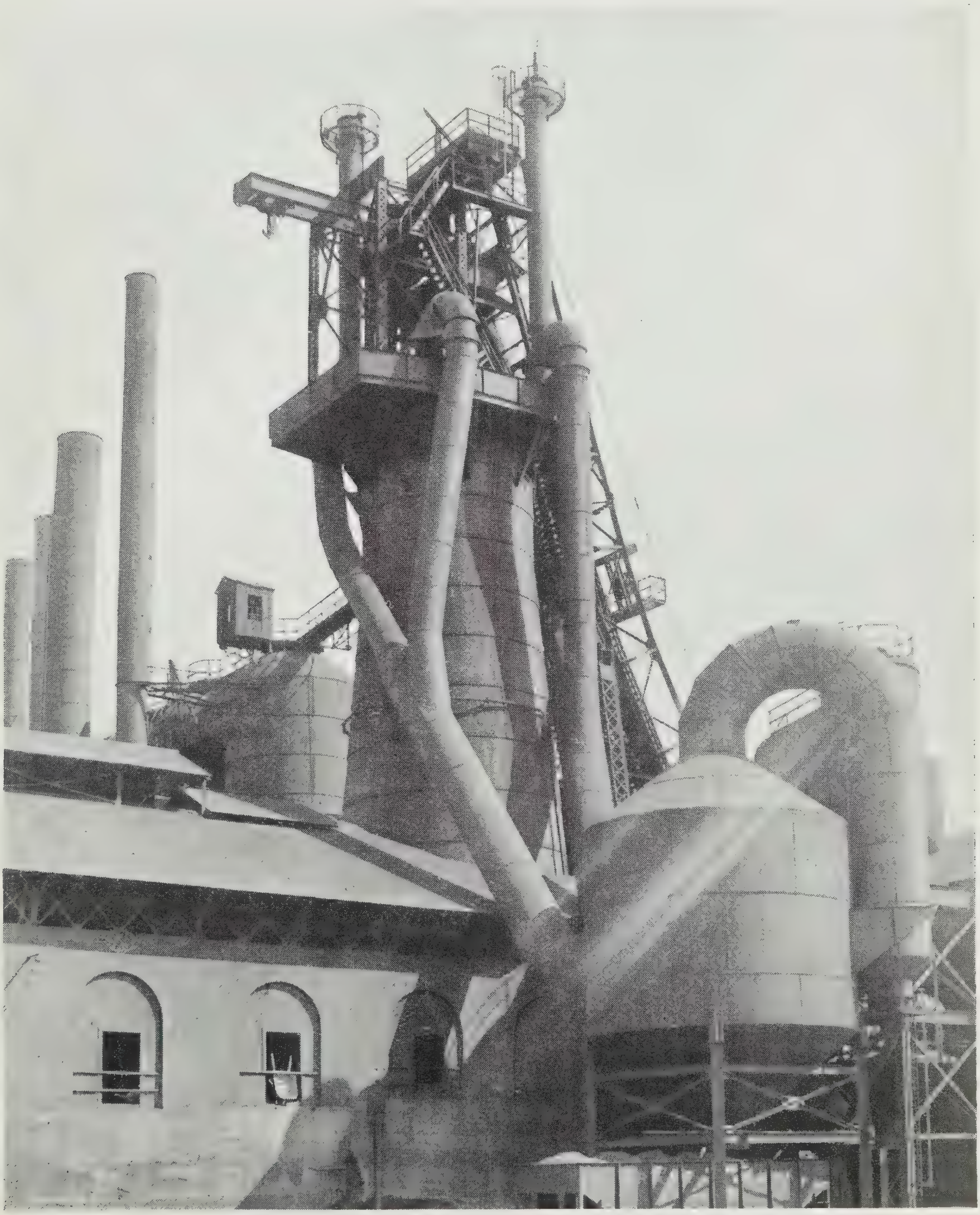


Fig. 28—"B" Furnace, Steel Company of Canada, Hamilton.

Due to market and other conditions during the first period, the burden on the furnace was changed every few days and this changing must be taken into consideration when using the results obtained.

At the time of these tests, the briquettes had disintegrated badly. They had been on the stock pile through the winter and not over 25 per cent. retained their original form. This was not undesirable except for the large amount of dust.

The furnace worked satisfactorily throughout the test and the results correspond to good average results obtained when using Lake Superior ores.

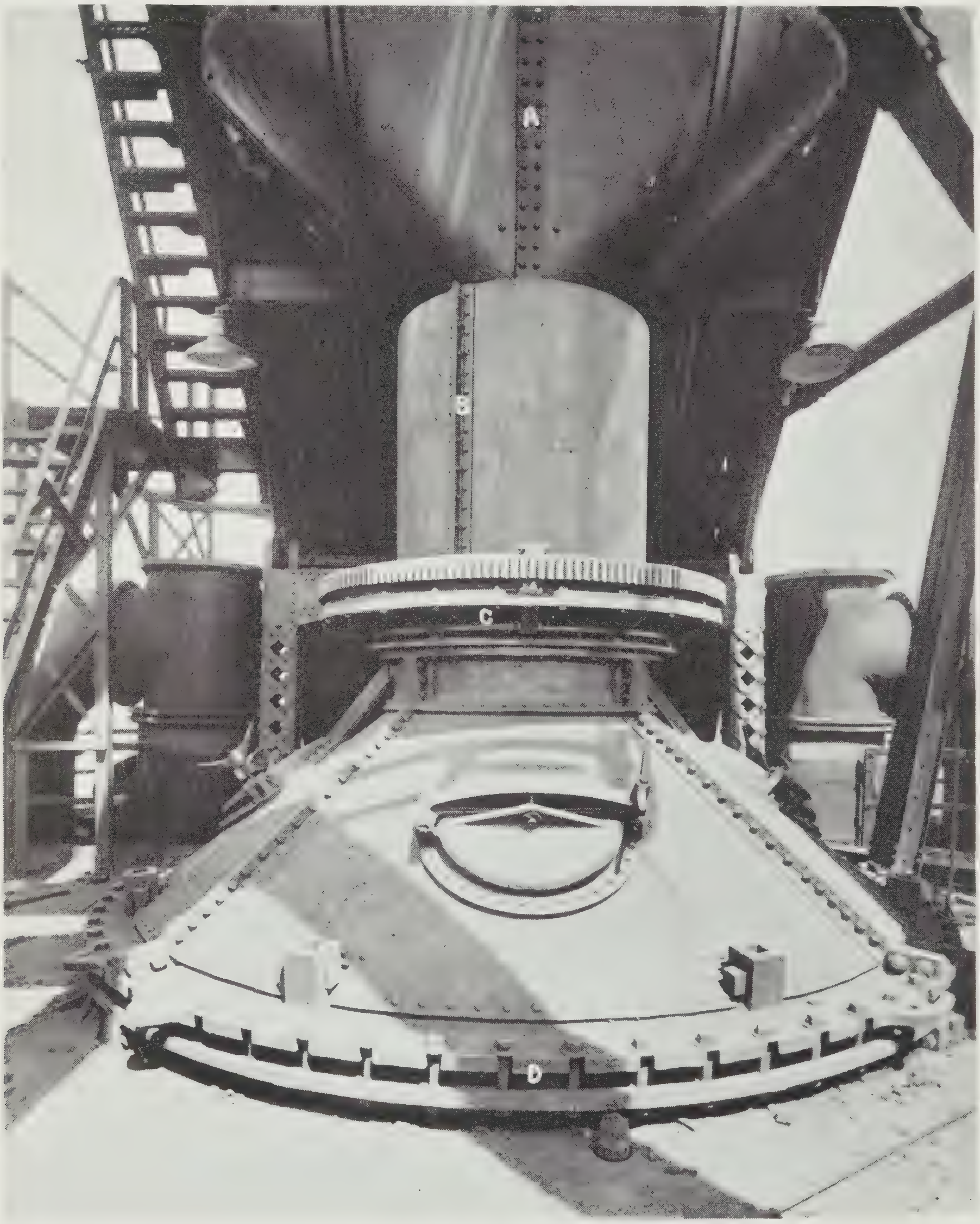


Fig. 29—Top of "B" Furnace, Steel Company of Canada, Hamilton.

BURDEN SHEET

Date: April 16th to 29th, 1923, inclusive
Mixture: Basic.
Furnace: "B."

STOCK	Fe	Phos.	Mn	SiO_2	Al_2O_3	CaO	MgO	S
	%	%	%	%	%	%	%	%
Plymouth	53.11	0.086	0.50	3.28	1.25	0.12	0.18	0.009
Osana	50.39	0.470	0.30	6.23	3.33	1.36	1.47	0.027
Richmond	39.69	0.043	0.11	37.33	0.99	0.42	0.36	0.001
Plymouth-Rex	47.45	0.082	2.86	3.29	1.57	0.17	0.15	0.013
Portsmouth-Rex	35.93	0.274	6.83	6.11	3.34	1.44	0.52	0.022
Danube	52.98	0.068	0.21	11.37	0.59	0.19	0.17	0.007
Moose Mountain	60.33	0.013	0.05	6.84	0.33	0.34	0.28	0.032
Scale	62.00	0.024	0.27	1.86	0.26	0.18	0.14	0.025
Hanover stone	......	......	......	0.45	0.30	54.35	0.62	0.025
Coke	......	......	......	5.48	3.33	0.72	0.34	1.06

MIXTURE	tons	%	Fe	Phos.	Mn	SiO_2	Al_2O_3	CaO	MgO	S
Plymouth	1,844	14.7	7.81	0.013	0.07	0.48	0.18	0.02	0.03	......
Osana	2,509	20.0	10.08	0.094	0.06	1.25	0.67	0.27	0.29	......
Richmond	318	2.5	0.99	0.001	......	0.93	0.02	0.01	0.01	......
Plymouth-Rex	75	0.6	0.28	......	0.02	0.02	0.01	......	......	......
Portsmouth-Rex	1,554	12.4	4.45	0.034	0.85	0.76	0.41	0.18	0.06	......
Danube	3,648	29.1	15.42	0.020	0.06	3.30	0.17	0.05	0.05	......
Moose Mountain	1,966	15.7	9.47	0.002	......	1.07	0.05	0.05	0.04	......
Scale	624	5.0	3.10	0.001	0.01	0.09	0.01	......	......	......
Average ore	12,538	100.0	51.60	0.165	1.07	7.90	1.52	0.58	0.48	......

WEIGHT OF CHARGE	tons	tons	tons	tons	tons	tons	tons	tons	tons
Ore	12,538	6,470	20.69	134	990	190	73	60	......
Coke	5,731	......	......	......	314	191	41	19	61
Stone	2,646	......	......	......	12	8	1,438	16	......
Scrap	......	......	......	......	......	......	......	......	......
Total charge	......	6,470	20.69	134	1,316	389	1,552	95	61

		tons	% Theoretical
SILICA IN CHARGE		1,316	
SiO_2 to provide 0.93 per cent. Si in pig		137	
SLAG	SiO_2	1,179	35.99
	Al_2O_3	389	11.87
	CaO	1,552	47.37
	MgO	95	2.89
	S	61	1.88
POUNDS SLAG PER TON PIG IRON, 1,066.	Total slag	3,276	100.00

IRON: 6,883 tons

	%
Yield	54.90
Phosphorus	0.30
Manganese	1.56
Silicon	0.93

BLAST FURNACE PRACTICE DATA

April 16th to 29th, 1923, inclusive

15 per cent. Moose Mountain briquettes		"B" furnace, basic
Time of operation	days	14
Total production	tons	6,448
Daily average production	"	460
Production per 24 hours per 100 cu. ft. volume	"	2.37
Total ore used	tons	11,914
Total cinder used		....
Total scale used	tons	624
Total extra scrap used		....
Total coke used	net tons	6,419
Total Hanover stone used	tons	2,646
Total Beachville stone used		....
Total all materials used	tons	21,603
Ore mixture per ton iron	lbs.	4,511
Scrap per ton iron	"	....
Coke per ton iron	"	1,994
Stone per ton iron	"	919
All material per ton iron	"	7,424
Silica in ore mixture	per cent.	7.90
Average coke ash	" "	11.17
Average coke sulphur	" "	1.07
Burden ratio	" "	2.19
Theoretical yield	per cent.	54.90
Actual yield	" "	51.43
Loss in yield	" "	3.47
Flue dust produced	tons	534.0
Flue dust per ton iron	lbs.	186
Average air temperature	degrees F.	52
Average grains moisture in air		2.97
Air per pound of coke	cu. ft.	50.4
Air per minute at 62° F.	"	33,872
Blast temperature	degrees F.	883
Top temperature	"	326
Average silicon in pig	per cent.	0.93
Average sulphur in pig	" "	0.041
Average phosphorus in pig	" "	0.26
Average manganese in pig	" "	1.37
Per cent. off sulphur iron	" "	4.8
Average silica in slag	per cent.	38.33
Average alumina in slag	" "	13.11
Average sulphur in slag	" "	1.88
Time lost	hrs. min.	11.32

BLAST FURNACE PRACTICE

Furnace "B," blown in January 19th, 1923.

Test Run, April 11th to 29th, 1922

Date	Mixture: Plymouth	Osana	Richmond	Plymouth-Rex	Portsmouth-Rex	Danube	Cedar	Moose Mountain	Scale	Burden: Ore	Coke	Stone	Scrap	SiO_2 in mixture	Fuel ratio	Charges	Extra coke
	%	%	%	%	%	%	%	%	%	lbs.	lbs	lbs	lbs	%	%		
16	15.0	20.0	2.5		12.5	30.0		15.0	5	26,200	12,000	5,550		7.95	2.19	77	
17	"	"	"		"	"		"	"	"	"	"		"	"	78	
18	"	"	"		"	"		"	"	"	"	"		"	"	78	
19	"	"	"		"	"		"	"	"	"	"		"	"	76	
20	"	"	"		"	"		"	"	"	"	"		"	"	74	
21	"	"	"		"	"		"	"	"	"	"		"	"	78	
22	"	"	"		"	"		"	"	"	"	"		"	"	82	
23	"	"	"		"	"		"	"	"	"	"		"	2.15	76	6
24	"	"	"		"	"		"	"	"	"	"		"	2.19	79	
25	"	"	"		"	"		"	"	"	"	"		"	"	80	
26	"	"	"		"	"		"	"	"	"	"		"	"	78	
27	"	"	"		"	"		"	"	"	"	"		"	"	74	
28	20.0	"	"		"	25.0		"	"	"	"	"		7.55	2.15	60	4
29	.	22.5	"	15.0	10.0	20.0		25.0	"	"	"	"		7.51	"	78	
Av	14.7	20.0	2.5	0.6	12.4	29.1		15.7	5	26,200	12,000	5,550		7.90	2.19	76	

Date	Blast: Cu. ft. per min. Actual	Cu. ft. per min. Equivalent at 62° F	Pressure	Temperature	Cu. ft. air per lb coke	Gr. moisture per cu. ft.	Product: Grade	Daily tonnage	Average for period	Analysis: Silicon	Sulphur	Phosphorus	Manganese	Per cent off	Slag: SiO_2	Al_2O_3	Sulphur
				° F				tons	tons	%	%	%	%	%	%	%	%
16	32,847	34,561	15.7	770	50.1	1.94		460	460	1.06	0.033	0.25	1.32		37.16	12.30	1.82
17	32,550	33,982	15.7	800	49.0	1.73		464	462	1.02	0.033	0.26	1.43		38.52	13.14	1.94
18	32,662	34,097	15.2	800	49.3	1.66		476	467	0.88	0.033	0.25	1.44		38.74	13.56	1.86
19	33,480	33,681	14.2	820	51.9	3.29		469	467	0.94	0.035	0.26	1.35		37.94	12.86	1.86
20	33,926	33,485	14.0	920	53.4	4.34		443	462	1.00	0.034	0.26	1.35		37.64	12.60	1.94
21	33,964	33,692	14.5	900	51.3	4.32		452	461	0.98	0.039	0.25	1.33				
22	34,484	35,070	15.0	980	49.6	3.80		511	469	0.82	0.049	0.25	1.34	16.0	38.42	14.34	1.90
23	33,405	34,173	18.0	880	50.9	2.66	Basic	466	468	1.01	0.045	0.27	1.51	16.6	38.98	13.84	1.88
24	33,331	34,030	15.0	900	49.6	2.74		469	468	0.89	0.047	0.25	1.47		38.72	14.18	1.90
25	33,480	33,982	15.0	920	49.4	2.66		483	469	0.92	0.048	0.25	1.38		39.68	12.46	1.88
26	33,442	33,643	14.0	1,050	50.4	2.73		464	469	0.91	0.047	0.26	1.37		38.04	12.28	1.86
27	32,664	33,350	16.0	930	49.6	3.26		441	466	0.81	0.051	0.26	1.15	16.0	38.58	12.60	1.86
28	31,843	32,636	16.0	920	51.4	3.30		399	461	0.98	0.046	0.26	1.35	16.0			
29	33,294	34,189	15.0	870	50.3	3.10		441	460	0.85	0.035	0.25	1.46		37.56	13.16	1.88
Av	33,241	33,872	15.2	883	50.4	2.97			460	0.93	0.041	0.26	1.37	4.8	38.33	13.11	1.88

Date	Coke: Daily	Period	Stone per ton	Top heat	Yield: Theoretical	Actual	Difference	Coke Analysis: Moisture	Ash	Sulphur	Coal mix: Mather	Hillman	Poca.	Time
	tons	tons	tons	F	%	%	%	%	%	%	%	%	%	hrs
16	2,008	2,008	929	324	54.9	50.9	4.0	2.50	12.22	1.08	80		20	24
17	2,017	2,013	933	320	"	51.3	3.6	1.87	10.84	1.06	59	21	"	"
18	1,966	1,997	911	312	"	52.6	2.3	1.87	12.02	1.10	80		"	"
19	1,900	1,984	901	325	"	53.2	1.7	1.87	10.66	1.06	80		"	"
20	2,004	1,989	927	315	"	51.2	3.7	2.50	11.04	1.09	56	24	"	"
21	2,070	2,003	959	328	"	49.8	5.1	1.87	10.76	1.06		80	"	"
22	1,929	1,989	892	318	"	53.6	1.3	2.19	11.08	1.04	51	29	"	"
23	1,986	1,989	905	315	"	52.4	2.5	1.87	11.28	1.09	57	23	"	"
24	2,021	1,992	913	325	"	51.2	2.8	1.87	11.38	1.07	8	72	"	"
25	1,983	1,992	917	340	"	52.1	2.8	1.87	10.80	1.08	66	14	"	"
26	2,017	1,994	932	330	"	51.2	3.7	2.19	11.34	1.09	80		"	"
27	2,014	1,996	933	345	"	51.4	3.5	1.87	11.48	1.07	57	23	"	"
28	1,827	1,987	833	347	"	57.3	2.4	1.87	10.22	1.06		80	"	"
29	2,122	1,994	980	315	"	48.8	6.1	1.87	11.12	1.07	80		"	"
Av		1,994	919	326	54.9	51.43	3.47	2.01	11.17	1.07	53	27	20	24

BURDEN SHEET

Date: April 30th to May 30th, 1923, inclusive.
Mixture: Basic.
Furnace: "B".

STOCK	Fe	Phos.	Mn	SiO_2	Al_2O_3	CaO	MgO	S
	%	%	%	%	%	%	%	%
Moose Mountain	60.33	0.013	0.05	6.84	0.33	0.34	0.28	0.032
Osana	50.39	0.470	0.30	6.23	3.33	1.36	1.47	0.027
Danube	52.98	0.068	0.21	11.37	0.59	0.19	0.17	0.007
Plymouth-Rex	47.45	0.082	2.86	3.29	1.57	0.17	0.15	0.013
Portsmouth-Rex	35.93	0.274	6.83	6.11	3.34	1.44	0.52	0.022
Cedar	48.92	0.125	0.23	7.88	4.25	0.99	2.11	0.019
Richmond	39.69	0.043	0.11	37.33	0.99	0.42	0.36	0.001
Scale	62.00	0.024	0.27	1.86	0.26	0.18	0.14	0.025
Scrap	90.00	......	......	......	......	......	......	......
Coke	......	......	......	5.38	3.10	0.73	0.32	1.05
Hanover stone	......	......	......	0.46	0.31	54.35	0.62	0.025
Beachville stone	......	......	......	0.65	0.65	53.45	1.29	0.025

MIXTURE	tons	%	Fe	Phos.	Mn	SiO_2	Al_2O_3	CaO	MgO	S
Moose Mountain	7,170	25.0	15.07	0.003	0.01	1.71	0.08	0.09	0.07	......
Osana	5,484	19.1	9.62	0.090	0.06	1.19	0.64	0.26	0.28	......
Danube	4,909	17.0	9.01	0.012	0.04	1.93	0.10	0.03	0.03	......
Plymouth-Rex	4,302	15.0	7.12	0.012	0.43	0.49	0.23	0.03	0.02	......
Portsmouth-Rex	2,892	10.0	3.59	0.027	0.68	0.61	0.33	0.14	0.05	......
Cedar	1,654	5.8	2.84	0.007	0.01	0.46	0.25	0.06	0.12	......
Richmond	907	3.1	1.23	0.001	......	1.16	0.03	0.01	0.01	......
Scale	1,434	5.0	3.10	0.001	0.01	0.09	0.01	0.01	0.01	......
Average ore	28,752	100.0	51.58	0.153	1.24	7.64	1.67	0.63	0.59	......

WEIGHT OF CHARGE	tons	tons	tons	tons	tons	tons	tons	tons	tons
Ore	28,752	14,830	43.99	357	2,097	481	181	170	......
Coke	13,172	......	......	......	709	408	97	42	138
Hanover stone	1,324	......	......	......	6	4	720	8	......
Beachville stone	4,679	......	......	......	30	30	2,501	60	......
Scrap	29	26	......	......	......	......	......	......	......
Total charge	......	14,856	43.99	357	2,842	923	3,499	280	138

		tons	% Theoretical
SILICA IN CHARGE		2,842	
	SiO_2 to provide 1.17 per cent. Si. in pig	268	
SLAG	SiO_2	2,574	34.72
	Al_2O_3	923	12.45
	CaO	3,499	47.19
	MgO	280	3.78
	S	138	1.86
POUNDS SLAG PER TON PIG IRON, 1,051.	Total slag	7,414	100.00

		%
IRON: 15,604 tons.	Yield	54.91
	Phosphorus	0.22
	Manganese	1.72
	Silicon	0.79

BLAST FURNACE DATA

April 30th to May 30th, 1923, inclusive

		"B" furnace, basic
Time of operation	days	31
Total production	tons	14,697
Daily average production	"	474
Production per 24 hours per 100 cu. ft. volume	"	2.44
Total ore used	tons	27,318
Total cinder used		....
Total scale used	tons	1,434
Total extra scrap used	"	29
Total coke used	net tons	14,752
Total Beachville stone used	tons	4,679
Total Hanover stone used	"	1,324
Total of all material	"	49,536
Ore mixture per ton iron	lbs.	4,382
Scrap per ton iron	"	4
Coke per ton iron	"	2,007
Stone per ton iron	"	915
All material per ton iron	"	7,308
Silica in ore mixture	per cent.	7.64
Average coke ash	" "	10.78
Average coke sulphur	" "	1.06
Burden ratio	" "	2.18
Theoretical yield	per cent.	54.90
Actual yield	" "	51.06
Loss in yield	" "	3.84
Flue dust produced	tons	976
Flue dust per ton iron	lbs.	149
Average air temperature	degrees F.	53
Average grains moisture in air		3.37
Air per pound coke	cu. ft.	50.7
Air per minute at 62° F.	"	34,725
Blast temperature	degrees F.	834
Top temperature	" "	287
Average silicon in pig	per cent.	0.79
Average sulphur in pig	" "	0.035
Average phosphorus in pig	" "	0.25
Average manganese in pig	" "	1.58
Per cent. off sulphur iron	" "	0.0
Average silica in slag	per cent.	37.25
Average alumina in slag	" "	12.88
Average sulphur in slag	" "	1.84
Time lost	hours	20.42

Furnace "B," blown in January 19th, 1923.

Test Run, April 30th to May 30th, 1923

Date	Mixture: [illegible]sar	Mixture: Richmond	Mixture: Plymouth-R.	Mixture: Portsmouth-Rex	Mixture: Danube	Mixture: Cedar	Mixture: Moose Mountain	Mixture: Scale	Burden: Ore	Burden: Coke	Burden: Stone	Burden: Scrap	SiO2 in mixture	Fuel ratio	Charge	Extra coke	Blast, Cu. ft. per min.: Actual	Blast, Cu. ft. per min.: Equivalent at 62° F.	Blast: Pressure	Blast: Temperature	Blast: Cu. ft. air per lb. coke	Blast: Gr. moisture per cu. ft.	Product: Grade
	%	%	%	%	%	%	%	%	Lbs.	lbs.	lbs.	lbs.	%							°F.			
[illegible]	22.5	2.5	15	10	20		25	5	[illegible]	12,0[illegible]	5,0[illegible]		[illegible]	[illegible]	[illegible]		33,480	34,484	15.7	870	49.9	3.[illegible]	Basic
1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]	80		33,405	33,938	14.0	900	49.2	2.49	"
[illegible]	"	[illegible]	"	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	"		[illegible]	[illegible]	80		33,331	34,330	14.5	900	49.5	2.47	"
[illegible]		"	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	"	[illegible]			[illegible]	[illegible]		32,029	32,898	15.0	900	48.4	2.65	"
[illegible]	[illegible]	"	"	[illegible]			[illegible]	[illegible]	"	[illegible]	[illegible]			[illegible]	[illegible]		33,700	33,970	15.0	900	50.9	3.03	"
5	"	"	"	"	"	....	"	"	"	"	"	...	"	"	79		33,852	34,425	15.0	910	51.9	3.53	"
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]		"		[illegible]	"	79		33,666	34,[illegible]77	16.0	850	50.0	3.[illegible]9	"
[illegible]	[illegible]	"	[illegible]	"	[illegible]		[illegible]	[illegible]	[illegible]	"	[illegible]	300	"	"	81		34,000	34,714	15.5	870	49.4	3.10	"
[illegible]	"	[illegible]	[illegible]	"	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]	[illegible]		34,220	35,007	15.0	900	51.3	4.68	"
9	"	"	"	"	"	....	"	"	"	"	"	...	"	2.18	77	.	33,628	35,177	16.5	770	50.9	2.84	"
10	"	"	"	"	"	....	"	"	"	"	"	...	"	"	81	.	34,000	35,428	15.0	780	49.5	2.44	"
11	"	"	"	"	"	....	"	"	"	"	"	...	"	"	80	..	34,224	35,452	15.0	800	50.2	3.07	"
12	"	"	"	"	"	....	"	"	"	"	"	....	"	"	80	..	34,220	35,452	15.0	850	50.3	3.05	"
13	"	"	"	"	"	....	"	"	"	"	"	....	"	"	82	..	34,150	35,243	14.5	860	49.0	2.50	"
14	"	"	"	"	"	....	"	"	"	"	"	....	"	"	81	...	34,150	35,243	15.0	900	49.5	2.88	"
15	"	"	"	"	"	....	"	"	"	"	"	...	"	"	78	.	34,410	34,341	14.5	900	52.1	5.32	"
16	"	"	"	"	"	....	"	"	"	"	"	....	"	"	75	..	34,744	33,744	15.0	850	50.3	4.59	"
17	"	"	"	"	"	....	"	"	"	"	"	.....	"	"	80	...	34,075	35,228	16.0	770	50.1	3.14	"
18	"	"	"	"	"	....	"	"	"	"	"	.....	"	"	79	.	34.670	35,398	15.0	700	51.7	3.31	"
[illegible]		"							"	[illegible]	"		[illegible]	"	78		34,[illegible]	34,664	15.0	[illegible]	51.6	3.05	[illegible]
[illegible]	"	[illegible]		[illegible]			"	[illegible]	36,5[illegible]		5,[illegible]50		"	2.1[illegible]	[illegible]	4	34,221	34,80[illegible]	15.7	750	51.6	4.05	"
[illegible]	[illegible]	[illegible]	[illegible]	"			[illegible]		"	[illegible]	"			2.[illegible]	[illegible]		34,0[illegible]	34,714	15.0	825	49.[illegible]	[illegible]	[illegible]
22	"	"	"	"	"	....	"	"	"	"	"	....	"	"	80	...	34,000	34,578	15.0	800	50.0	2.78	"
[illegible]	[illegible]	"	"	[illegible]			"	[illegible]	26,70[illegible]	[illegible]	"		"	2.21	[illegible]		3[illegible],480	34,116	15.5	750	51.7	[illegible]	"
		[illegible]							[illegible]	[illegible]	5,1[illegible]		[illegible]	[illegible]	78		34,5[illegible]	34,76[illegible]	15.0	[illegible]	51.1	[illegible]	"
[illegible]	15.0	5.0	[illegible]	[illegible]	1	10			[illegible]	"	5,8[illegible]		19	2.21	[illegible]		[illegible]	34,14[illegible]	15.0	850	[illegible]	4.83	"
[illegible]		[illegible]				[illegible]	[illegible]	[illegible]	[illegible]					[illegible]	[illegible]		34,5[illegible]	34,2[illegible]7	[illegible]	[illegible]	[illegible]	4.[illegible]	"
[illegible]			[illegible]				[illegible]			[illegible]	"		[illegible]	"	8[illegible]		35,0[illegible]	35,120	15.0	830	50.[illegible]	3.10	"
[illegible]	"	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				[illegible]	[illegible]		3[illegible],[illegible]70	34,427	16.[illegible]	[illegible]	[illegible]	4.2	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]			[illegible]	79	4	35,15[illegible]	[illegible]	[illegible]	[illegible]	51.[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	"	[illegible]	[illegible]	[illegible]	"	[illegible]		"	[illegible]	[illegible]		"	[illegible]	81		[illegible]	[illegible]	[illegible]	[illegible]	51.3	[illegible].25	"
Av.	19.1	[illegible]	17	10	1[illegible]	[illegible]	[illegible]		2[illegible]	1[illegible]	[illegible],511	[illegible]	[illegible].4	[illegible]	[illegible]		34,117	34,7[illegible]	15.5	[illegible]	50.[illegible]	3.[illegible]	Basic

Date	Product: Daily tonnage	Product: Average per period	Analysis: Silicon	Analysis: Sulphur	Analysis: Phosphorus	Analysis: Manganese	Per cent off	Slag: SiO2	Slag: Al2O3	Slag: Sulphur	Coke: Daily	Coke: Period	Coke per ton	Top heat	Yield: Theoretical	Yield: Actual	Yield: Difference	Coke analysis: Moisture	Coke analysis: Ash	Coke analysis: Sulphur	Coal mix: Mather	Coal mix: Hillman	Coal mix: P.	Time
	tons	tons	%	%	%	%		%	%	%	tons	tons	tons	°F.	%	%	%	%	%					hr. min.
[illegible]	470	47[illegible]	0.8[illegible]	0.0[illegible]4	0.[illegible]5	1.72		36.80	1[illegible].16	1.92	1,991	1,991	920	325	[illegible]	51.5	[illegible]	3.42	10.92	1.08	61	1[illegible]	20	22 [illegible]
1	478	477	0.80	0.03[illegible]	0.26	1.50		37.64	12.14	1.88	2,008	2,00[illegible]	920	315	[illegible]	51.8	2.8	1.87	10.92	1.08	56		"	[illegible]
[illegible]	483	478	0.83	0.036	0.2[illegible]	1.64		[illegible]7.06	12.18	1.84	2,[illegible]8	2,013	9[illegible]	311	[illegible]	51.9	2.[illegible]	1.87	11.[illegible]4	1.12	14	[illegible]	"	[illegible]
[illegible]	411	4[illegible]1	0.88	0.041	0.27	1.56		3[illegible].92	12.36	1.86	1,[illegible]75	1,99[illegible]	[illegible]	[illegible]	[illegible]	52.1	2.5	[illegible].81	11.34	1.08	59	21	[illegible]	[illegible]
[illegible]	499	[illegible]	0.80	0.041	0.[illegible]	1.7[illegible]		38.02	1[illegible].22	1.86	1,875	1,972	8[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.87	11.[illegible]2	1.0[illegible]	49	31	[illegible]	[illegible]
5	497	474	0.78	0.035	0.26	1.64	....	......	.....	.....	1,907	1,960	882	392	"	54.2	0.4	1.87	10.50	1.06	53	27	"	"
[illegible]	466	472	0.79	0.03[illegible]	0.26	1.6[illegible]		38.91	12.80	1.94	2,058	1,971	913	[illegible]	"	50.8	3.8	1.87	10.6[illegible]	1.19	[illegible]		[illegible]	"
[illegible]	504	47[illegible]	0.69	0.037	0.2[illegible]	1.5[illegible]		38.7[illegible]	12.22	1.8[illegible]	1,[illegible]	1,9[illegible]	892	[illegible]	[illegible]	[illegible]	1.[illegible]	1.87	10.2[illegible]	1.0[illegible]	18	[illegible]	"	"
[illegible]	471	47[illegible]	0.79	0.04[illegible]	0.[illegible]	1.6[illegible]		[illegible]	13.01	1.92	1,957	1,9[illegible]	919	[illegible]	"	[illegible]	2.6	1.87	10.26	1.00	[illegible]		"	[illegible]
9	473	475	0.90	0.035	0.28	1.66	...	37.94	13.28	1.82	1,953	1,966	901	284	"	52.5	2.1	2.50	11.04	0.90	68	12	"	"
10	508	478	0.76	0.038	0.25	1.61	....	38.80	12.42	1.82	1,913	1,961	884	274	"	53.4	1.2	1.87	11.08	1.04	. .	80	"	"
11	495	480	0.82	0.034	0.26	1.59	....	38.56	13.76	1.88	1,939	1,959	895	275	"	52.5	2.1	1.87	10.36	1.06	74	6	"	"
12	504	482	0.79	0.033	0.25	1.55	....	......	.....	.....	1,904	1,955	882	260	"	54.3	0.3	2.19	10.86	1.02	80	..	"	20 48
13	500	483	0.83	0.032	0.25	1.76	..	37.60	13.66	1.86	1,968	1,956	910	276	"	52.6	2.0	2.50	11.52	1.06	35	45	"	"
14	502	484	0.90	0.035	0.24	1.60	...	37.02	14.08	1.92	1,936	1,955	894	257	"	53.0	1.6	2.50	10.52	1.07	80	. .	"	"
15	484	484	0.78	0.032	0.25	1.63	...	36.94	13.38	1.94	1,934	1,953	894	260	"	53.5	1.1	2.50	11.48	1.09	80	. .	"	"
16	418	480	0.72	0.036	0.24	1.45	...	37.18	12.42	1.90	2,392	1,963	995	246	"	48.1	6.5	2.19	10.64	0.99	62	18	"	"
17	472	480	0.86	0.031	0.23	1.69	...	36.64	13.42	1.88	2,033	1,967	940	259	"	50.9	3.7	2.50	10.74	1.08	54	26	"	"
18	462	479	0.70	0.028	0.23	1.64	....	36.64	12.42	1.90	2,052	1,972	945	279	"	50.4	4.2	2.19	10.46	1.07	46	34	"	"
[illegible]	45[illegible]	477	0.69	0.031	0.2[illegible]	1.[illegible]					[illegible]	1,950	999	275	"	45.0	6.6	[illegible].50	11.[illegible]	1.0[illegible]	[illegible]		[illegible]	"
[illegible]	435	475	[illegible].6[illegible]	[illegible].039	0.21	1.[illegible]		[illegible].14	1[illegible]	1.[illegible]	[illegible]	1,987	9[illegible]5	2[illegible]	[illegible]	[illegible]	[illegible]	2.5[illegible]	1[illegible]	1.0[illegible]				
[illegible]	459	4[illegible]	0.75	[illegible]	[illegible].23	1.50		[illegible]	1[illegible]	1.88	2,091	1,991	952	28[illegible]	[illegible]	39.0	[illegible]	[illegible].50	11.11	1.19	[illegible]	10[illegible]	"	
22	497	475	0.83	0.034	0.23	1.54	...	36.08	13.24	1.96	1,931	1,989	861	294	"	53.0	1.6	1.87	11.68	1.06	56	24	"	"
[illegible]	44[illegible]	4[illegible]	[illegible]	[illegible]	[illegible].24	[illegible]		[illegible]	1[illegible]	1.88	2,11[illegible]	1,99[illegible]	94[illegible]	[illegible]	[illegible]	[illegible]1	[illegible]	[illegible].50	10.[illegible]	1.11		[illegible]		[illegible]
[illegible]	453	473	0.71	0.041	0.[illegible]1	1.[illegible]		[illegible]	13.60	1.78	2,025	1,99[illegible]	86[illegible]	[illegible]	[illegible]	50.0	4.[illegible]	[illegible].50	10.5[illegible]	1.07		[illegible]	"	[illegible]
[illegible]	468	47[illegible]	[illegible]	[illegible].042	0.24	1.[illegible]5		[illegible]	1[illegible].78	1.84	1,91[illegible]	1,9[illegible]	[illegible]	[illegible]		[illegible].7	9	[illegible]	[illegible]	1.[illegible]			[illegible]	"
[illegible]	457	472	[illegible]	0.0[illegible]	0.23	1.5[illegible]					2,0[illegible]	[illegible]	9[illegible]	250		[illegible]	[illegible]	[illegible]	1[illegible]	1.07	[illegible]	10[illegible]		
[illegible]	496	47[illegible]	[illegible]	0.03[illegible]	0.23	1.12		37.02	13.12	1.86	1,959	1,9[illegible]	[illegible]	2[illegible]		[illegible].5	3.1	1.87	10.[illegible]	1.[illegible]	[illegible]			
[illegible]	478	4[illegible]	[illegible]	[illegible].033	0.[illegible]	1.1[illegible]		[illegible]	1[illegible].80	1.84	[illegible]	1,9[illegible]	[illegible]	[illegible]		[illegible]	5.4	1.[illegible]	10.7[illegible]	1		[illegible]		
[illegible]	494	471	0.9[illegible]	0.035	0.2[illegible]	1.[illegible]		[illegible]7.8	12.36	1.[illegible]	1,951	1,9[illegible]	887	300	[illegible]	[illegible]	1.[illegible]	1.[illegible]	10.5	1.0	[illegible]		[illegible]	
[illegible]	474	47[illegible]	0.88	0.037	0.[illegible]	1.1[illegible]		[illegible]	[illegible]	1.[illegible]	[illegible]	1,[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	11	1			[illegible]	
Av.		4[illegible]4	0.79	0.03[illegible]	0.2	1.[illegible]		[illegible].25	1[illegible].8	1.[illegible]		2,0[illegible]7	9[illegible]	[illegible]	5[illegible]	[illegible]		[illegible]	[illegible]	1.0	[illegible]	[illegible]	[illegible]	[illegible]

Reports on Samples of Steel

The following is a report by O. W. Ellis on samples of steel manufactured from iron produced in the blast furnace with a 25 per cent. charge of Moose Mountain magnetite ore.

Two samples were taken from each of three different heats, Nos. 5161, 6172, and 7144. The rods from which samples were taken in connection with heat number 5161, were three-quarters of an inch in diameter. The rods from which samples were taken in connection with heats Nos. 6172 and 7144, were five-eighths of an inch in diameter. The results of the tests show the steels examined to be possessed of mechanical properties normal to alloys of the analyses quoted.

Below are full particulars of the results of the tests:—

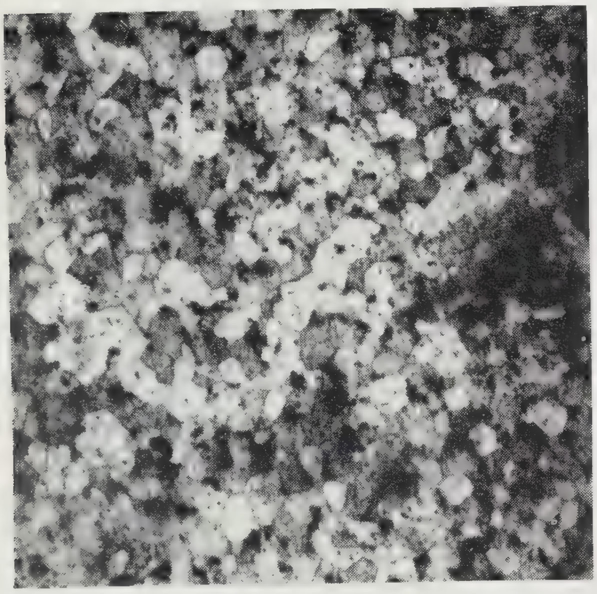


Fig. 30

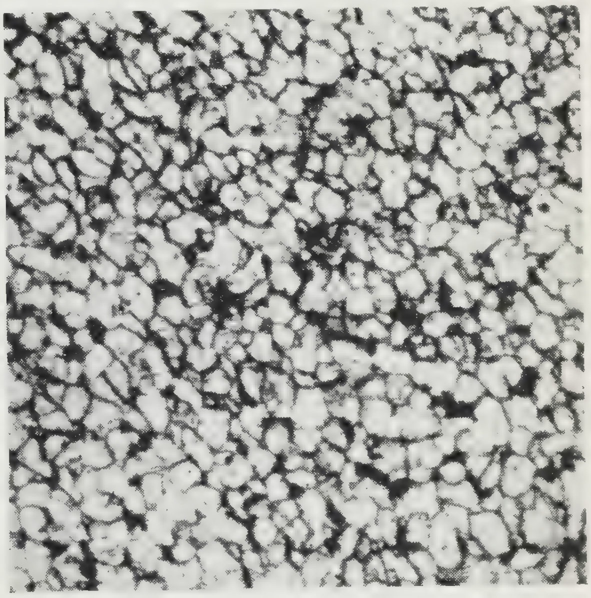


Fig. 31

Fig. 30—Photomicrograph showing the structure of a transverse section of rod No. 5161—magnification, 100 diameters, The sample has been etched in such a way as to render the ferrite grains distinguishable and at the same time to leave the pearlite grains clearly visible.

Fig. 31—Photomicrograph showing the structure of a longitudinal section of rod No. 5161—magnification, 100 diameters. The sample has been deeply etched to bring out the character of the ferrite grains. The pearlite areas are somewhat masked as a result of the deep etching; they can, however, be distinguished by careful examination.

HEAT No. 5161

Chemical Analysis

	per cent.
Carbon	0.10
Manganese	0.35
Sulphur	0.039
Phosphorus	0.015

No. of sample	Yield point, lbs. per sq. in.	Ultimate stress, lbs. per sq. in.	Elongation on 2 inches	Contraction of area
			per cent.	per cent.
1	29,720	52,070	41.5	74.5
2	38,350	50,880	44.5	68.5
Mean value	34 035	51,475	43.0	71.5

	inches
Size of rod	¾ diameter
Gauge length of test sample	2
Diameter of test sample	0.50±

HEAT No. 6172

Chemical Analysis

	per cent.
Carbon	0.10
Manganese	0.37
Sulphur	0.037
Phosphorus	0.020

No. of sample	Yield point, lbs. per sq. in.	Ultimate stress, lbs. per sq. in.	Elongation on 2 inches	Contraction of area
			per cent.	per cent.
5	39,260	50,270	48.5	75.5
6	41,870	52,100	....[1]	74.0
Mean value	40,565	51,185	48.5	74.75

[1]Error in marking gauge length of sample.

	inches
Size of rod	⅝ diameter
Gauge length of test sample	2
Diameter of test sample	0.50±

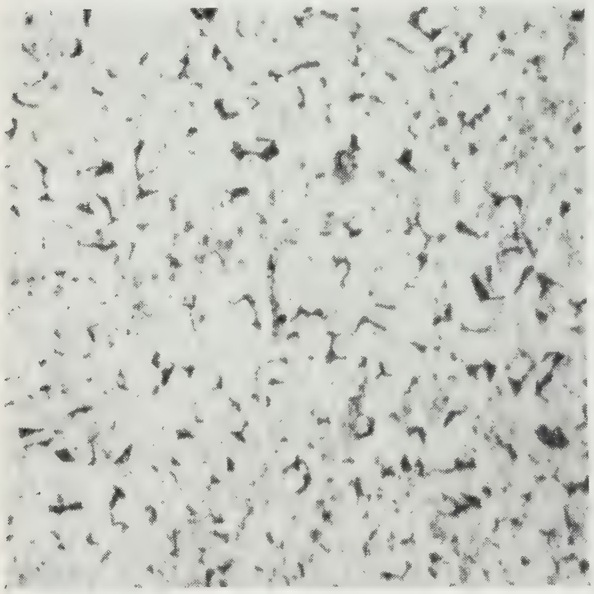


Fig. 32

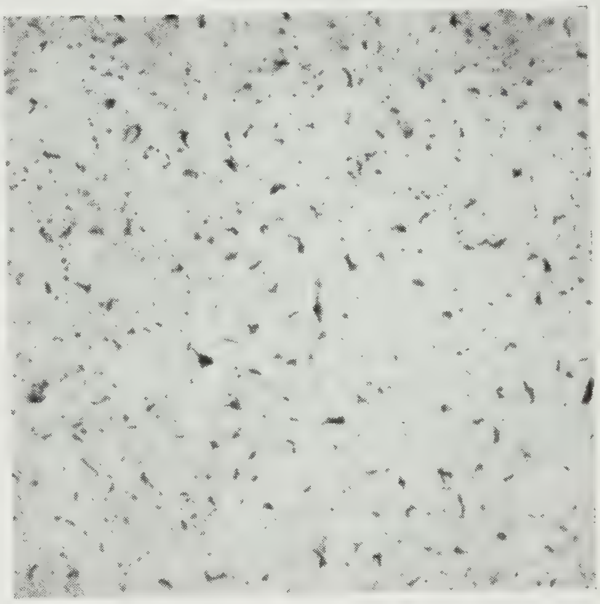


Fig. 33

Fig. 32—Photomicrograph showing the structure of a transverse section of rod No. 6172—magnification, 100 diameters. The dark areas represent pearlite, the light areas ferrite.

Fig. 33—Photomicrograph showing the structure of a transverse section of rod No. 7144—magnification, 100 diameters. The dark areas represent pearlite, the light areas ferrite.

HEAT No. 7144

Chemical Analysis

	per cent.
Carbon	0.09
Manganese	0.34
Sulphur	0.039
Phosphorus	0.015

No. of sample	Yield point, lbs. per sq. in.	Ultimate stress, lbs. per sq. in.	Elongation on 2 inches	Contraction of area
			per cent.	per cent.
3	44,460	48,080	51.5	78.0
4	42,220	48,180	50.0	74.5
Mean value	43,340	48,130	50.75	76.25

	inches
Size of rod	⅝ diameter
Gauge length of test sample	2
Diameter of test sample	0.50±

APPENDIX

TO THE

REPORT OF THE ONTARIO IRON ORE COMMITTEE

Containing information on transportation, etc., description of Ontario iron ore deposits, special articles on prospecting and metallurgy, and a bibliography.

PART I

I. TRANSPORTATION

The cost of transporting iron ore from mine to smelter is, of course, a very important factor in the final cost of production of iron and steel. The railways in Canada, with a view to assisting in the development of iron ore deposits, have established and published a scale of rates applicable between points in Canada as follows:—

RATES PER GROSS TON FOR CARLOAD LOTS OF IRON ORE APPLICABLE BETWEEN POINTS IN CANADA

(Exclusive of bog iron ore)

Distances	Rates	Distances	Rates
	cents		cents
Not exceeding 50 miles	120	Over 225 and not over 250 miles	200
Over 50 and not over 100 miles	130	" 250 " " " 275 "	220
" 100 " " " 125 "	140	" 275 " " " 300 "	230
" 125 " " " 150 "	150	" 300 " " " 325 "	240
" 150 " " " 175 "	170	" 325 " " " 350 "	250
" 175 " " " 200 "	180	" 350 " " " 375 "	260
" 200 " " " 225 "	190	" 375 " " " 400 "	270

The importance of the mining industry in the United States, from a railway tonnage standpoint, is illustrated by the following figures, which are taken from official statistics showing the tonnage carried by Class 1 railroads during the year 1921:—

Total tons carried	1,691,617,051
Products of mines	878,645,798[1]

or 52 per cent. of the total tonnage carried.

The tonnage of manufactured articles (iron and steel) carried during 1921 was as follows:—

	Net tons
Iron, pig, and bloom	10,327,601
Rails and fastenings	5,117,193
Bar and sheet iron, structural iron, and iron pipe	30,099,023
Other metals, pig, bar, and sheet	5,668,383
Castings, machinery, and boilers	8,687,866

[1]The iron ore included in this total amounted to 48,453,203 tons.

In addition to the above, the following table is shown to indicate other rates for transportation available during the year 1922:—

RATES PER GROSS TON ON IRON ORES APPLICABLE BETWEEN POINTS IN CANADA AND THE UNITED STATES

To	From							
	Sellwood, Ont.	Helen Mine, Ont.	Babbitt Mine. Minn.	Lake Superior Ports	Michipicoten, Ont	Superior, Wis.	Marquette, Mich.	Escanaba, Mich.
	cents	cents	cents	cents	cents	cents	cents	cents
Ashtabula Harbor, Ohio				80				
Ashtabula, Ohio (for furtherance)	*a*387							
Bethlehem, Pa	*a*576							
Black Rock, N.Y. (local)	*ab*351							
Buffalo, N.Y. (for furtherance)	*ac*324							
Chester, Pa	*a*437							
Detroit. Mich			*d*336					
Duluth, Minn			*e* 90					
Farrell, Pa	*af*558							
Hamilton, Ont	*a*210		*g*316	*h*230				
Johnson City, Tenn	*a*702							
Michipicoten, Ont		*i* 80						
Pittsburgh, Pa			*j*293 *k*289	203				
Point Edward, Ont			*l*166	80				
Port Colborne, Ont				80				
Sault Ste. Marie, Ont	*m*210				*n*35	*n* 42	*n*31½	*n* 35
Sharon, Pa	*af*558							
Suspension Bridge, N.Y. (for furtherance)	*a*198							
Toledo, Ohio				80				
Two Harbors, Minn			*o* 86					
Welland, Ont	*a*220							
West Middlesex, Pa	*af*558							
Youngstown, Ohio	*af*558							

a Iron ore briquettes.
b Exclusive of connecting lines switching charges on traffic for local delivery.
c Rates include delivery to connecting lines on traffic destined beyond.
d All rail movement, distance 713 miles.
e Rate includes assembling at point of origin.
f Exclusive of switching at destination.
g Rate based 86 cents rail to Two Harbors, plus 80 cents water to Point Edward, plus Canadian mileage scale beyond.
h Rate based 80 cents water to Point Edward, plus Canadian mileage scale beyond 140 miles.
i Rate includes handling at Michipicoten, Ont., and applies on iron ore pyrites when the United States is the destination.
j Via Two Harbors, "Lake," Ashtabula, Ohio, and "Rail."
k Via Duluth, "Lake," Ashtabula Harbor, and "Rail."
l Rate based 86 cents rail to Two Harbors, plus 80 cents water beyond.
m Applies on iron ore concentrates.
n Net to vessel; unloading charge at Sault Ste. Marie averages 15 cents per ton.
o Includes assembling, weighing, and sorting at point of origin, and storage for 10 days. Unloading from cars and loading to vessel 5 cents per gross ton additional.

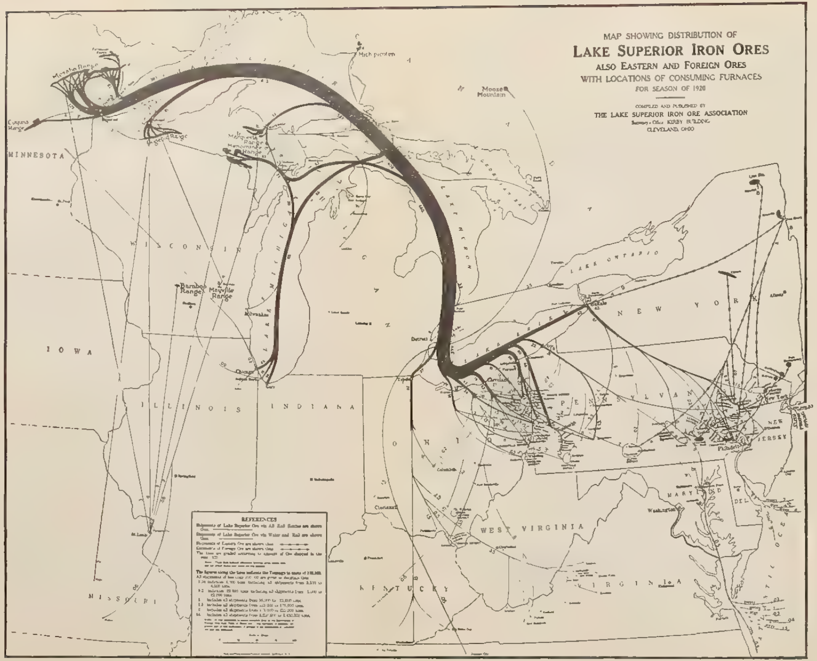


Fig. 34—Map showing distribution of Lake Superior iron ores in 1920.

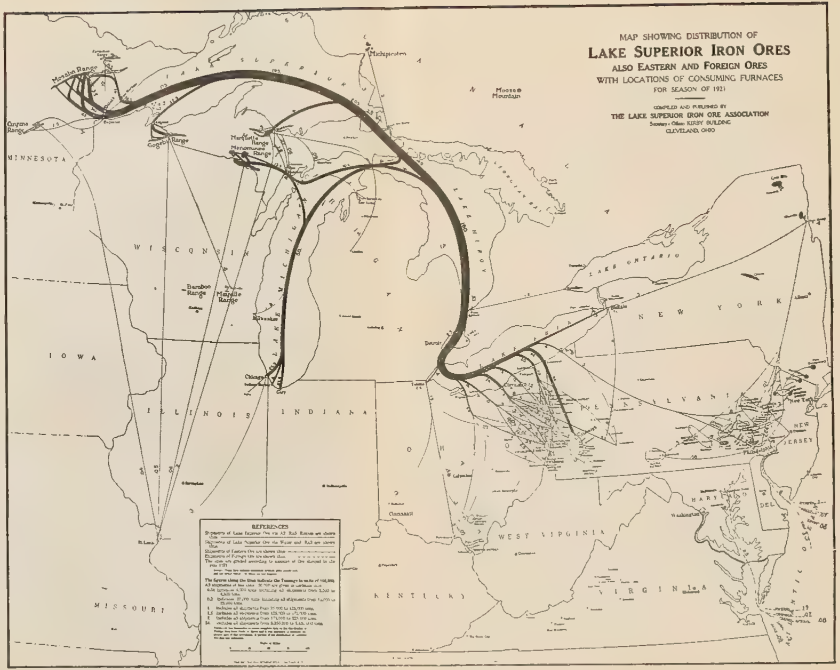


Fig. 35—Map showing distribution of Lake Superior iron ores in 1921.

The following figures show in gross tons the amount of ore moved from the Mesabi and Vermilion ranges for the years 1918 to 1922.

Year	Mesabi range	Vermilion range
	tons	tons
1922	28,055,394	1,211,467
1921	16,349,896	869,313
1920	37,147,705	1,007,433
1919	32,003,169	920,049
1918	40,396,215	1,192,908

The movement covers points of destination varying in distance up to 1,000 miles, which would be the average distance between the mines referred to and Pittsburgh.

RECEIPTS OF ORE AT POINTS IN CANADA

	1921	1920	1919	1918
	tons	tons	tons	tons
Sault Ste. Marie	293,151	725,123	550,539	711,068
Parry Sound	....	....	....	23,288
Midland	....	18,265	4,998	67,194
Point Edward	174,191	331,879	350,757	251,575

Figures 34 and 35 show in detail the ore movement in 1920 and 1921.

WATER TRANSPORTATION FACILITIES FOR LAKE SUPERIOR IRON ORES

Trip Capacity of Lake Freighters for Season of 1922

Company	Number of vessels	Capacity per trip
		tons
Pittsburgh Steamship Co.	97	791,900
Interlake Steamship Co.	51	402,800
M. A. Hanna & Co.	28	268,100
Hutchinson & Co.	21	178,400
Great Lakes Steamship Co.	20	153,100
G. A. Tomlinson	18	155,100
Boland & Cornelius	16	139,900
Cleveland-Cliffs Iron Co.	15	125,000
Oglebay, Norton & Co.	12	96,500
Wilson Transit Co.	10	84,700
Reiss Steamship Co.	8	65,300
Shenango Steamship Co.	5	58,200
Becker Steamship Co.	8	58,100
Interstate Steamship Co.	4	44,000
H. K. Oakes	4	41,000
H. H. Brown & Co.	4	38,200
D. Sullivan & Co.	5	38,100
A. T. Kinney	4	25,100
H. & G. M. Steinbrenner	4	32,700
C. O. Jenkins	3	27,100
Valley Camp Steamship Co.	4	23,300
Paisley Steamship Co.	4	23,100
Morrow Steamship Co. (Paisley)	3	20,000
C. W. Bryson	3	13,200
Other steamship companies (9)	12	87,600
Total for 33 companies	363	3,010,500

Average vessel capacity, per trip, 8,293 tons.

DOCK FACILITIES OFFERED LAKE SUPERIOR ORES FOR LOADING AT HEAD OF THE LAKES

Place	Number of docks	Storage capacity
		tons
DULUTH, MINN.—		
Duluth, Superior & Northern Railway	3	345,600
SUPERIOR, WIS.—		
Great Northern Railway	3	300,600
Northern Pacific Railway	1	70,700
Soo Line (Minneapolis, St. Paul & Sault Ste. Marie Railway)	1	120,600
TWO HARBORS, MINN.—		
Duluth & Iron Range Railroad	4	186,600
ASHLAND, WIS.—		
Chicago & Northwestern Railway	3	213,100
Soo Line (Minneapolis, St. Paul & Sault Ste. Marie Railway)	1	52,500
ESCANABA, MICH.—		
Chicago & Northwestern Railway	4	232,000
Chicago, Milwaukee & St. Paul Railway	2	90,000
MARQUETTE, MICH.—		
Duluth, South Shore & Atlantic Railway	1	45,000
Lake Superior & Ishpeming Railway	1	50,000
Total	24	1,706,700

DISTRIBUTION OF ORES, LAKE MOVEMENT FROM LAKE SUPERIOR DISTRICT

	1919	1920	1921	1922
	tons	tons	tons	tons
Ashtabula	8,377,277	11,028,518	2,001,806	7,978,718
Cleveland	7,466,921	7,857,163	2,559,390	7,357,509
Conneaut	7,056,882	5,989,763	5,329,396	6,799,037
Buffalo	4,868,334	8,384,153	1,183,883	3,918,870
Lorain	3,379,421	4,030,571	1,788,175	2,885,168
Fairport	1,952,635	1,247,964	1,340,017	1,118,721
Toledo	1,536,437	2,654,957	411,241	1,216,115
Erie	1,102,478	2,218,658	386,627	617,017
Huron	1,134,104	1,421,509	553,806	669,573
Detroit	549,096	813,381	269,488	736,970
Total Lake Erie ports	37,423,585	45,646,637	15,823,829	33,297,788
Total lake front furnaces, Lake Erie ports	8,008,265	10,181,680	3,251,409	9,106,242
Total inland furnaces	29,415,320	35,464,957	12,770,951	24,191,546
Total Lake Michigan ports	8,629,377	11,354,732	5,816,616	8,954,005
Total miscellaneous ports	906,294	1,075,267	490,065	640,831
On docks, Lake Erie ports, December 1st	10,456,314	10,955,868	9,032,595	10,000,000

2. COMPOSITION OF IRON ORES

Iron Ore Minerals

The principal iron ores found in the Lake Superior region are hematite, limonite, magnetite, and siderite. Turgite and goethite are commercially included with limonite. The residues from roasting the sulphides for the manufacture of sulphuric acid are sometimes used as a source of iron, and some ilmenite is smelted with other ores. The minerals described are:—

Mineral	Composition	Crystallization
Oxides:		
Hematite	Fe_2O_3	Hexagonal
Magnetite	Fe_3O_4	Isometric
Martite	Fe_2O_3	Isometric
Ilmenite	$(FeTi)_2O_3$	Hexagonal
Hydroxides:		
Limonite	$Fe_2(OH)_6Fe_2O_3$	
Turgite	$Fe_4O_5(OH)_2$	
Goethite	$FeO(OH)$	Orthorhombic
Carbonate:		
Siderite	$FeCO_3$	Hexagonal
Sulphides:		
Pyrite	FeS_2	Isometric
Pyrrhotite	Fe_6S_7 to $Fe_{11}S_{12}$	Hexagonal
Marcasite	FeS_2	Orthorhombic

Hematite

Composition.—Fe_2O_3; contains 70 per cent. iron.

Description.—Occurs in masses which are compact, granular, or sometimes micaceous, and as loose, pulverulent earth. It varies in colour from brilliant black metallic to brick red. In all varieties the streak on porcelain is red. The hardness varies from 5.5 to 6.5, and the specific gravity from 4.9 to 5.3.

Magnetite

Composition.—Fe_3O_4; contains 72.4 per cent. iron.

Description.—A black mineral with a black streak on porcelain; metallic lustre; strongly attracted by the magnet; occurring in all conditions from loose sand to compact, coarse, or fine-grained masses. The hardness varies from 5.5 to 6.5, and the specific gravity from 4.9 to 5.2.

Martite

Composition.—Fe_2O_3; contains 70 per cent. iron.

Description.—Differs from hematite in form. It occurs in octahedrons which it is supposed were derived from the oxidation of magnetite.

Ilmenite

(Iron Titanium Compound)

Composition.—$(FeTi)_2O_3$; composition variable.

Description.—An iron black mineral, usually massive, occurring in thin plates, as imbedded grains, or as sand. The streak on porcelain is black to brownish red. The hardness varies from 5 to 6, and the specific gravity from 4.5 to 5.

Limonite

Composition.—$Fe_2(OH)_6Fe_2O_3$; contains 59.8 per cent. iron.

Description.—Varies from loose, porous bog ore and ochre to compact varieties which often have a black, varnish-like surface and a fibrous radiated structure. It is recognized principally by its yellowish brown streak on porcelain and absence of crystallization. The hardness varies from 5 to 5.5, and the specific gravity from 3.6 to 4.

Turgite

Composition.—$Fe_4O_5(OH)_2$; contains 66.2 per cent. iron.

Description.—Nearly black and resembles limonite, but has a brownish red streak on porcelain. The hardness varies from 5.5 to 6, and the specific gravity from 4.3 to 4.7.

Goethite

Composition.—$FeO(OH)$; contains 62.9 per cent. iron.

Description.—A yellow, red, or brown mineral occurring in distinct crystals, often flattened like scales, or needle-like and grouped in parallel positions; also occurs massive like yellow ochre. The streak on porcelain is yellow, or brownish yellow. The hardness varies from 5 to 5.5, and the specific gravity from 4 to 4.4.

Siderite

Composition.—$FeCO_3$; contains 48.2 per cent. iron.

Description.—Occurs in granular masses of a gray or brown colour, or may be black from included carbonaceous matter. The lustre is vitreous to pearly, and the mineral is brittle. The streak on porcelain is white or pale yellow. The hardness is 3.5 to 4, and the specific gravity 3.8 to 3.9.

Pyrite

Composition.—FeS_2; contains 46.7 per cent. iron, 53.3 per cent. sulphur.

Description.—A brass-coloured metallic mineral, frequently in cubic or other isometric crystals, or in crystalline masses; less frequently in non-crystalline masses. The streak on porcelain is greenish-black, the hardness 6 to 6.5, and the specific gravity 4.9 to 5.2.

Pyrrhotite

Composition.—Fe_6S_7 to $Fe_{11}S_{12}$; composition variable.

Description.—Usually a massive, bronze, metallic mineral which is attracted by the magnet and can be scratched with a knife. The streak on porcelain is grayish-black, the hardness 3.5 to 4.5, and the specific gravity 4.5 to 4.6.

Marcasite

Composition.—FeS_2; same as pyrite.

Description.—Differs from pyrite in form. Crystallizes in orthorhombic forms which have received the names of cockscomb pyrites, spear pyrites, etc. The streak on porcelain is nearly black, the hardness 6 to 6.5, and the specific gravity 4.6 to 4.9.

Analyses of Lake Superior Ores

AVERAGE ANALYSES OF TOTAL TONNAGE, ALL GRADES

Range	Year	Tonnage	Average iron (nat.)	Average phosphorus	Average silica	Average manganese	Average moisture
			per cent.	per cent.	per cent.	per cent.	per cent.
GOGEBIC	1922	6,161,589	52.90	0.065	7.89	0.80	11.36
	1921	2,313,846	52.10	0.061	9.20	0.58	11.72
	1920	8,098,437	52.75	0.066	7.63	0.77	11.93
	1919	5,856,226	52.95	0.063	7.74	0.63	11.66
	1918	7,884,525	52.52	0.069	7.88	0.72	11.90
	1917	7,481,405	52.75	0.068	8.08	0.72	11.58
	1916	8,372,406	53.21	0.064	7.60	0.64	11.63
	1915	5,389,749	53.74	0.066	7.35	0.61	11.18
	1914	3,518,765	54.00	0.061	7.15	0.52	11.28
	1913	4,370,192	53.66	0.053	7.74	0.51	11.05
	1912	4,892,285	53.74	0.055	7.94	0.55	10.84
	1911	2,410,961	54.00	0.051	7.28	0.57	11.08
	1910	4,289,262	53.39	0.050	7.90	0.66	11.00
	1909	3,951,502	52.83	0.052	8.01	0.78	11.66
	1908	2,669,488	53.23	0.052	7.87	0.64	11.05
	1907	3,568,251	53.14	0.050	7.46	0.85	11.18
	1906	3,603,388	53.57	0.051	7.06	0.76	11.07
	1905	3,613,595	54.43	0.049	6.05	0.67	11.14
	1904	2,389,026	54.66	0.045	6.05	0.63	10.78
	1903	2,864,001	55.02	0.048	5.51	0.80	10.60
	1902	3,338,918	55.12	0.048	5.50	0.69	10.87
MARQUETTE	1922	2,847,478	51.89	0.124	10.50	0.[illegible]7	9.62
	1921	1,105,791	50.95	0.138	11.87	0.38	9.78
	1920	4,208,148	51.70	0.122	11.11	0.36	9.69
	1919	2,636,186	51.06	0.148	11.87	0.37	9.63
	1918	4,248,869	52.31	0.112	10.45	0.37	9.42
	1917	4,570,928	51.56	0.132	9.70	0.42	10.31
	1916	5,264,627	51.90	0.125	9.89	0.41	9.93
	1915	3,937,937	52.57	0.113	10.22	0.41	9.81
	1914	2,393,886	51.60	0.102	10.53	0.42	9.26
	1913	3,832,319	51.94	0.111	9.82	0.40	9.70
	1912	3,920,103	52.20	0.154	8.81	0.49	10.65
	1911	2,779,695	51.82	0.102	10.54	0.45	10.15
	1910	4,254,273	51.36	0.121	9.93	0.40	9.70
	1909	4,103,406	52.68	0.098	9.88	0.37	8.76
	1908	2,381,453	52.53	0.101	9.58	0.33	9.90
	1907	4,037,768	53.39	0.113	9.11	0.40	9.33
	1906	4,007,789	54.27	0.115	8.40	0.40	9.20
	1905	4,140,599	54.59	0.110	8.13	0.35	8.80
	1904	2,786,275	55.21	0.093	7.54	0.41	8.32
	1903	2,990,848	54.83	0.102	7.99	0.33	8.37
	1902	3,825,694	54.84	0.097	8.30	0.34	7.61
MENOMINEE	1922	3,982,770	50.16	0.35[illegible]	8.76	0.56	8.04
	1921	1,570,289	50.82	0.347	8.15	0.36	7.79
	1920	6,460,244	50.20	0.332	9.22	0.57	7.62
	1919	4,388,731	50.52	0.375	8.23	0.57	8.07
	1918	6,294,806	50.02	0.353	9.42	0.53	7.99
	1917	5,866,821	50.16	0.324	9.34	0.60	7.94
	1916	6,168,908	50.25	0.333	9.43	0.59	7.86
	1915	4,763,611	50.52	0.348	8.72	0.60	7.81
	1914	2,953,338	49.61	0.319	11.76	0.45	7.35
	1913	4,694,534	49.14	0.311	11.19	0.53	7.46
	1912	4,341,036	49.34	0.330	11.44	0.55	7.55
	1911	3,720,900	49.25	0.320	11.80	0.51	7.54
	1910	4,203,429	49.65	0.298	11.54	0.38	7.55
	1909	4,904,195	49.90	0.308	10.87	0.34	7.70
	1908	2,742,608	49.14	0.263	12.99	0.41	7.29
	1907	4,793,129	49.46	0.259	12.62	0.53	7.40
	1906	5,135,271	49.68	0.254	12.61	0.54	7.21
	1905	4,425,971	50.46	0.236	12.52	0.37	7.10
	1904	3,038,833	51.21	0.239	11.60	0.36	7.39
	1903	3,592,418	50.72	0.189	11.84	0.50	6.85
	1902	4,350,783	51.11	0.179	11.82	0.35	7.00

AVERAGE ANALYSES OF TOTAL TONNAGE, ALL GRADES—*Continued.*

Range	Year	Tonnage	Average iron (nat.)	Average phosphorus	Average silica	Average manganese	Average moisture
			per cent.	per cent.	per cent.	per cent.	per cent.
VERMILION........	1922	1,200,008	56.67	0.055	9.56	0.12	5.73
	1921	860,632	58.60	0.049	6.53	0.12	5.84
	1920	940,118	58.62	0.057	6.79	0.10	5.63
	1919	872,061	58.60	0.059	6.66	0.12	5.85
	1918	1,157,674	57.90	0.057	7.71	0.14	5.72
	1917	1,482,948	58.02	0.055	7.55	0.14	5.69
	1916	1,926,332	57.95	0.054	7.55	0.11	5.87
	1915	1,704,789	58.02	0.051	6.87	0.14	6.28
	1914	1,004,170	58.56	0.058	6.38	0.13	5.94
	1913	1,547,832	58.77	0.052	6.37	0.12	5.78
	1912	1,826,934	59.18	0.054	6.09	0.11	5.52
	1911	1,075,535	59.59	0.051	6.01	0.11	5.07
	1910	1,192,415	60.14	0.054	5.18	0.11	5.02
	1909	1,097,127	60.49	0.053	4.84	0.11	5.06
	1908	832,924	60.57	0.048	4.55	0.12	5.14
	1907	1,668,049	60.42	0.043	5.08	0.10	5.28
	1906	1,785,871	60.60	0.044	4.73	0.09	5.31
	1905	1,648,610	61.14	0.047	4.37	0.13	4.95
	1904	1,269,689	60.37	0.045	4.53	0.12	5.13
	1903	1,659,932	60.86	0.048	4.55	0.12	4.85
	1902	2,045,892	61.65	0.052	3.95	0.12	4.32
CUYUNA..........	1922	1,481,521	46.01	0.218	8.65	3.99	10.75
	1921	483,719	49.66	0.175	8.90	1.59	11.45
	1920	2,108,497	46.61	0.211	9.05	3.29	11.39
	1919	1,777,266	48.35	0.292	8.60	1.99	11.54
	1918	2,399,790	43.87	0.200	9.85	5.15	11.47
	1917	2,220,263	48.06	0.199	8.92	2.52	10.92
	1916	1,421,644	48.31	0.179	9.07	2.32	11.32
	1915	897,782	50.06	0.224	9.06	0.50	10.75
	1914	736,573	50.09	0.193	10.02	0.27	11.59
TOTAL OLD RANGE.	1921	6,334,277	52.28	0.153	9.02	0.51	9.58
	1920	21,815,444	51.45	0.169	8.87	0.85	9.90
	1919	15,530,470	51.73	0.191	8.62	0.70	9.96
	1918	21,985,664	51.10	0.172	9.03	1.05	9.93
	1917	21,622,365	51.68	0.164	8.81	0.77	9.85
	1916	23,153,917	52.22	0.156	8.70	0.64	9.74
	1915	16,693,868	52.79	0.164	8.46	0.51	9.37
	1914	10,606,732	52.40	0.151	9.32	0.42	9.25
	1913	14,444,877	52.28	0.152	9.27	0.45	8.96
	1912	14,980,358	52.73	0.161	8.96	0.48	9.19
	1911	9,987,091	52.23	0.166	9.73	0.66	8.86
	1910	13,939,379	52.22	0.147	9.39	0.45	9.05
	1909	14,056,230	52.36	0.155	9.30	0.46	8.92
	1908	8,626,473	52.44	0.132	9.65	0.43	8.97
	1907	14,067,197	52.82	0.138	9.41	0.53	8.66
	1906	14,432,319	53.28	0.139	9.08	0.50	8.50
	1905	13,828,775	54.01	0.126	8.54	0.41	8.41
	1904	9,483,823	55.45	0.122	8.06	0.41	8.21
	1903	11,107,199	54.45	0.108	8.08	0.47	7.92
	1902	13,611,287	54.74	0.104	8.05	0.40	7.73

AVERAGE ANALYSES OF TOTAL TONNAGE, ALL GRADES—*Continued*

Range	Year	Tonnage	Average iron (nat.)	Average phosphorus	Average silica	Average manganese	Average moisture
			per cent.	per cent.	per cent.	per cent.	per cent.
MESABI	1922	27,757,928	51.99	0.062	7.92	0.67	11.39
	1921	16,189,712	51.98	0.061	7.92	0.67	11.49
	1920	36,122,984	51.84	0.063	7.69	0.73	11.81
	1919	31,136,408	51.50	0.066	7.75	0.75	12.03
	1918	39,987,207	51.39	0.066	7.63	0.78	12.04
	1917	40,899,100	51.25	0.065	7.60	0.75	12.47
	1916	42,037,986	50.64	0.065	7.61	0.78	12.60
	1915	29,189,620	50.74	0.066	7.96	0.72	12.39
	1914	20,827,364	50.81	0.067	7.65	0.76	12.35
	1913	33,461,455	50.97	0.063	7.50	0.76	12.51
	1912	30,882,865	51.20	0.064	7.44	0.73	11.90
	1911	21,514,092	51.12	0.063	7.75	0.72	11.90
	1910	28,426,801	51.42	0.065	7.27	0.76	12.05
	1909	27,903,438	51.59	0.062	6.60	0.79	12.56
	1908	17,117,611	52.66	0.059	6.24	0.70	11.95
	1907	26,162,592	52.95	0.058	5.48	0.62	11.87
	1906	23,168,539	53.44	0.057	5.56	0.62	11.68
	1905	19,846,629	54.24	0.051	4.86	0.56	11.45
	1904	11,952,165	55.45	0.047	4.58	0.54	10.26
	1903	12,622,751	55.19	0.047	4.75	0.52	10.38
	1902	13,165,814	56.07	0.045	4.35	0.52	9.71
GRAND TOTAL ALL RANGES	1922	43,431,294	51.87	0.099	8.23	0.76	10.78
	1921	22,523,989	52.07	0.087	8.23	0.62	10.95
	1920	57,938,428	51.69	0.103	8.13	0.77	11.09
	1919	46,666,878	51.57	0.108	8.04	0.73	11.34
	1918	61,972,871	51.29	0.104	8.12	0.87	11.29
	1917	62,521,465	51.40	0.099	8.02	0.76	11.57
	1916	65,191,903	51.20	0.097	8.00	0.73	11.58
	1915	45,883,488	51.49	0.100	8.14	0.64	11.29
	1914	31,434,096	51.34	0.095	8.21	0.65	11.30
	1913	47,906,332	51.37	0.090	8.03	0.66	11.44
	1912	45,863,223	51.69	0.096	7.93	0.65	11.01
	1911	31,501,183	51.47	0.095	8.38	0.64	10.93
	1910	42,366,180	51.68	0.092	7.97	0.66	11.06
	1909	41,959,668	51.85	0.093	7.51	0.68	11.33
	1908	25,744,084	52.58	0.083	7.39	0.61	10.95
	1907	40,229,789	52.91	0.086	6.86	0.59	10.75
	1906	37,600,858	53.38	0.088	6.91	0.57	10.46
	1905	33,675,404	54.14	0.082	6.37	0.50	10.20
	1904	21,435,988	55.02	0.080	6.12	0.48	9.36
	1903	23,729,950	54.84	0.075	6.31	0.50	9.23
	1902	26,777,101	55.39	0.075	6.23	0.46	8.71

3. YEARLY MARKET PRICE, LAKE SUPERIOR IRON ORES AT LOWER LAKE PORTS

Year	Old Range		Mesabi	
	Bess.	Non-Bess.	Bess.	Non-Bess.
1900	$5.50	$4.15	$4.40	$4.00
1901	4.25	2.85	2.75	2.35
1902	4.25	3.00	3.00	2.60
1903	4.50	3.60	4.00	3.20
1904	3.00	2.60	2.75	2.35
1905	3.75	3.20	3.50	3.00
1906	4.25	3.70	4.00	3.50
1907	5.00	4.20	4.75	4.00
1908	4.50	3.70	4.25	3.50
1909	4.50	3.70	4.25	3.50
1910	5.00	4.20	4.75	4.00
1911	4.50	3.70	4.25	3.50
1912	3.75	3.00	3.50	2.85
1913	4.40	3.60	4.15	3.40
1914	3.75	3.00	3.50	2.85
1915	3.75	3.00	3.45	2.80
1916	4.45	3.70	4.20	3.55
1917	5.95	5.20	5.70	5.05
1918 Jan. 1 to June 30	5.95	5.20	5.70	5.05
1918 July 1 to Sept. 30	6.40	5.65	6.15	5.50
1918 Oct. 1 to Dec. 31	6.65	5.90	6.40	5.75
1919	6.45	5.70	6.20	5.55
1920	7.45	6.70	7.20	6.55
1921	6.45	5.70	6.20	5.55
1922	5.95	5.20	5.70	5.05
1923	6.45	5.70	6.20	5.55

Base ore content (natural state), 1906 and some previous years: Bessemer 56.70, non-Bessemer 52.80; 1907 and later: Bessemer 55.00, non-Bessemer, 51.50.

4. MAGNETIC PROSPECTING FOR IRON ORE

By A. L. Parsons

In preparing the following discussion on prospecting for iron ores by magnetic means, the writer has attempted to show certain features that may be of use to the prospector. It does not pretend to be a compendium on the subject, nor is a complete bibliography of the work on magnetic mapping given. The theory of magnetism is not discussed at all, and formulae for determining magnetic intensity are omitted.

The principles governing magnetic mapping by compass, dip needle, and magnetometer have been discussed by Haanel,[1] Smyth,[2] and Hotchkiss, Bean, and Wheelwright,[3] and many others.

In view of the location and development of commercial ranges of iron ore by means of the compass and dip needle in Wisconsin and Minnesota, the writer is inclined to favour this method as at least a preliminary in a magnetic examination, though he is well aware that both compass and dip needle have serious limitations. For the most reliable results this preliminary work should be supplemented by a magnetometric survey, so that measurements may be made and recorded for three planes.

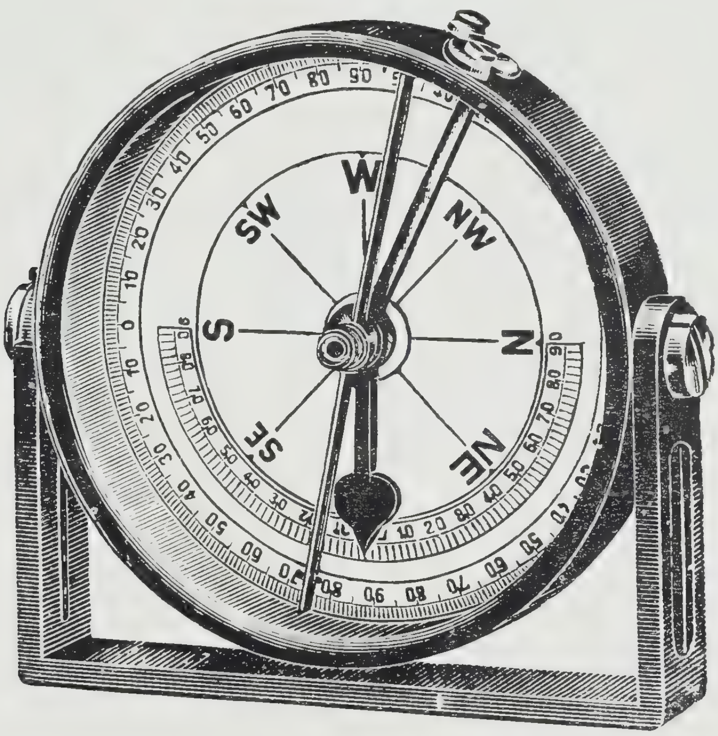


Fig. 36—Clinometer and sight compass combined. The sights may be turned at right angles when using as a compass.

The Compass

The compass (Fig. 36) consists of a bar magnet suspended on a pivot, so that the point of suspension is above the centre of gravity and so compensated as to swing in a horizontal plane. By this means the magnetic meridian is obtained. A special type of compass which is provided with a sun-dial and is known as the "dial compass" (Fig. 37) enables the observer to determine the magnetic variation within reasonable limits of error, without transit observations.

The Dip Needle

The dip needle (Fig. 38) is a compass which is provided with an axis suspended between two bearings so that the needle will swing in a vertical plane, and is so compensated that it is horizontal in the normal earth field when held in the magnetic meridian. (In using this instrument it is held so that the needle swings in the magnetic meridian, so that it is first necessary to

[1]Haanel, E., On the Location and Examination of Magnetic Ore Deposits by Magnetometric Measurements: Can. Dept. Mines, Canada, Mines Branch.

[2]Smyth, H. S., U.S. Geol. Survey, Mon. XXXVI, Pt. II, Ch. 2.

[3]Hotchkiss, W. O., Bean, E. G., and Wheelwright, O. W., Wisconsin Geol. and Nat. Hist. Survey, Bull. XLIV, pp. 75-136.

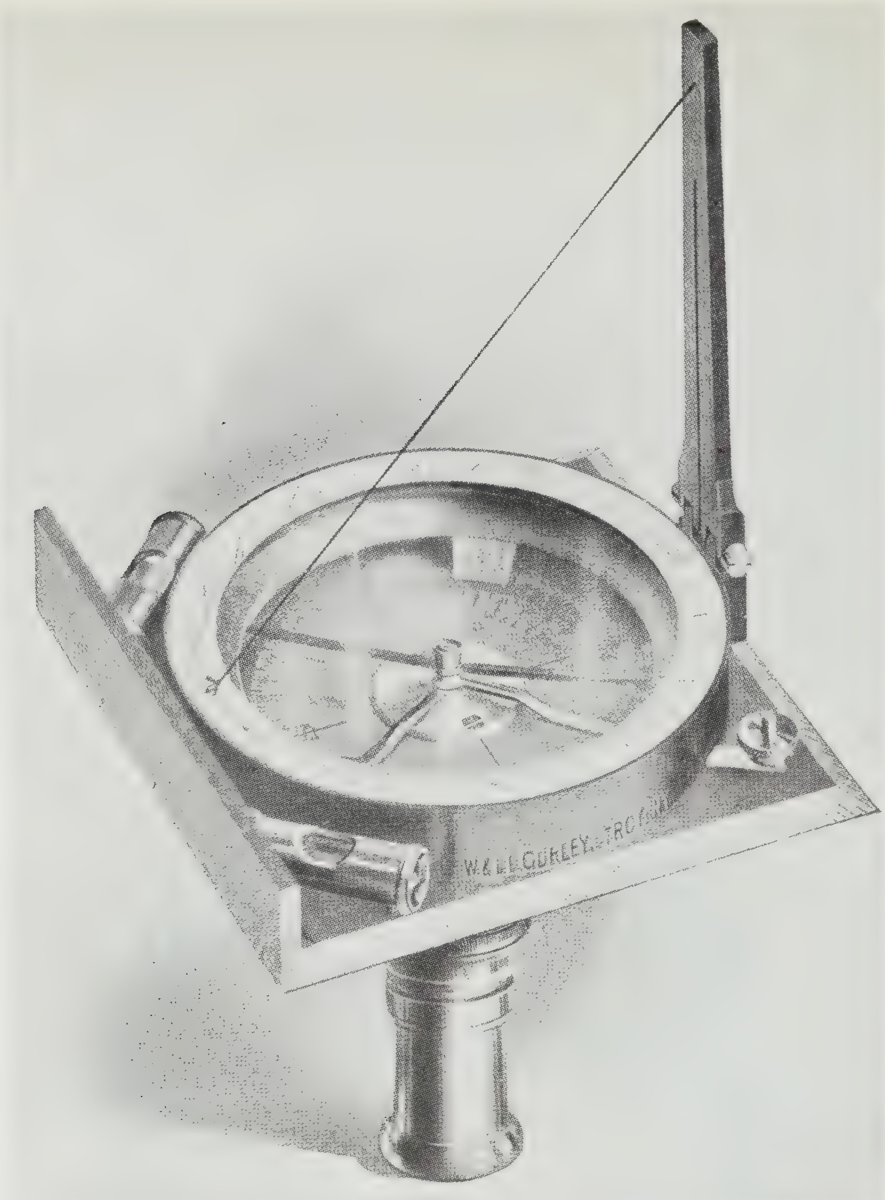


Fig. 37—Dial compass, mounted on Jacob's staff or tripod, used in localities where there is local attraction and a simple means of determining the meridian is desired.

Fig. 38—Miner's or dip compass. The needle is suspended to swing in a vertical plane. It records the intensity of the magnetic attraction.

locate this meridian by the compass. For rough work the dip needle may be used to determine this meridian, but for purposes of record the compass is necessary.)

The most delicate results are obtained from a needle which, while compensated for the magnetic meridian, will give a dip of 90° in the vertical plane at right angles to the meridian.

The Magnetometer[1]

In the magnetometer (Fig. 39) the compass is so compensated that when held vertically, so that the plane of rotation of the needle is at right angles to the magnetic meridian in the earth field, the needle will be horizontal. When held over a magnetic body at right angles to the magnetic meridian induced by that body, the needle will dip and a measure of vertical intensity is obtained. In practice, after the compass (or inclinator) has been compensated, the field readings are frequently made with the inclinator alone.

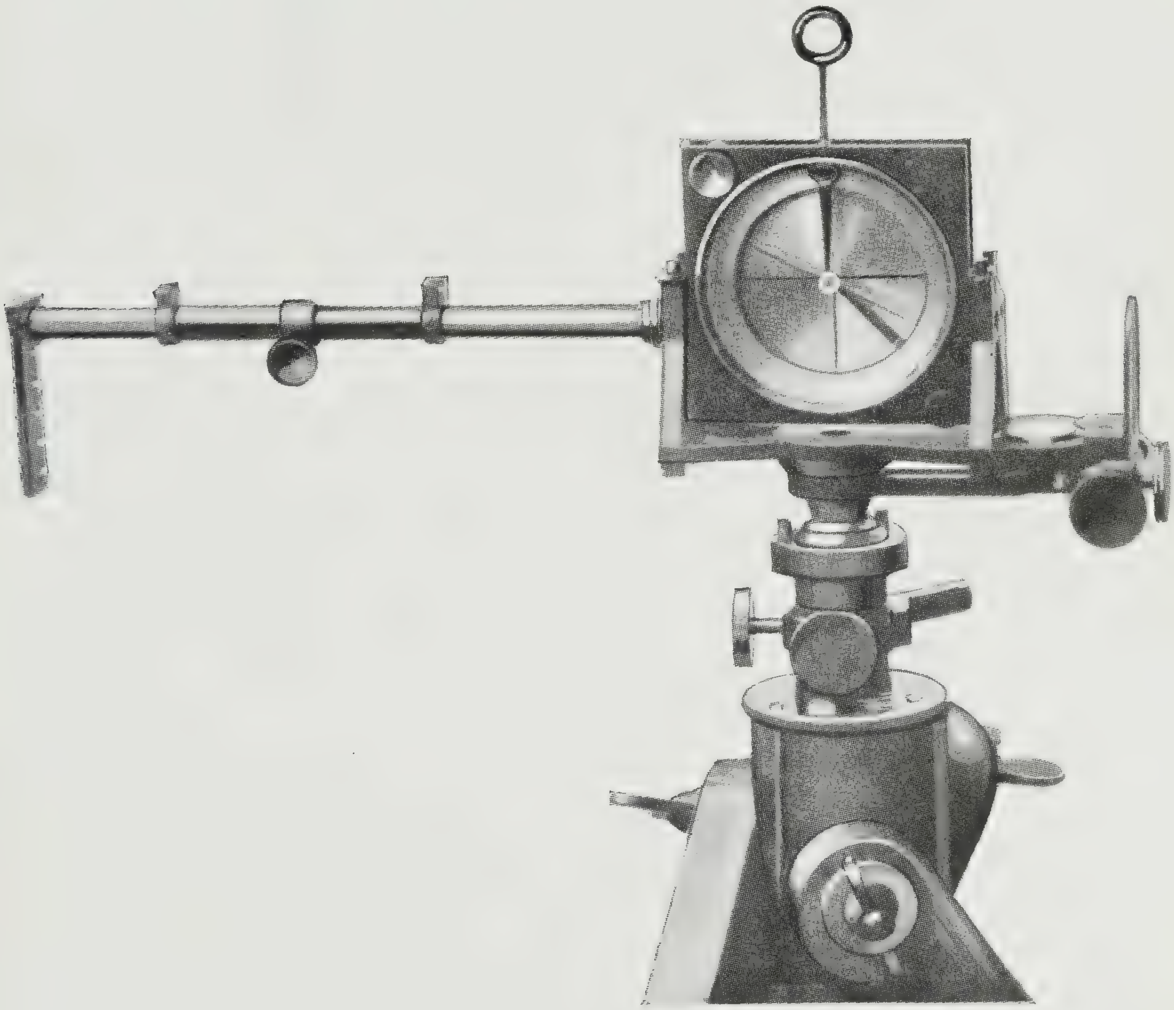


Fig. 39—Magnetometer, Thalen-Tiberg (after Haanel).

Measurements in Three Planes

With these three instruments, then, there is a means of obtaining magnetic measurements in three planes at right angles to each other. Before incurring the expense of diamond drilling, it is desirable to have a map showing measurements in all three planes; it is also necessary for a correct interpretation of the results to have a contour map and as much geological information as can be obtained.

Interpretation of Magnetic Readings

The person using results obtained by these instruments should be one who has the requisite knowledge to correlate the information so as to minimize the chance of drilling useless holes. He must understand the conditions that govern the magnetic phenomena observed, for while it is comparatively easy to show the effect of a bar magnet on compass, dip needle, and magnetometer, the problem becomes more complicated when ore deposits which may be multipolar are examined. He should also understand that under certain conditions even strongly magnetic bodies fail to affect one or more of the compass, dip needle, and the inclinator of the magnetometer, and that the best ore may underlie such an area of balanced magnetic forces.

[1]The reader is referred to the most excellent work by Haanel for a complete description (Op cit.)

Effect of Bar Magnet on Compass

In order to show the necessity of having readings in three directions, it will be well to consider what happens when a compass is passed over a bar magnet horizontally and vertically, both parallel with and at right angles to the length of the magnet. The position of the magnet with respect to the earth's magnetic meridian has a marked effect on the phenomena observed, so that an arbitrary position will be taken with the north-seeking pole of the magnet pointing south (Fig. 40). As the compass is advanced from the south, it will point north until C_1 is approached where the magnetic force of the earth's field neutralizes the magnetic force of the magnet. This is known as a neutral point and the compass is very sluggish. As the compass is moved from this point towards N, it will point south; as it passes N, it again points north until S is reached, when it points south as far as C_2; after which it again points north.

If the compass is moved along a line parallel with the bar, but at one side, the phenomena observed will be the same as for the dip needle, which is next described, but in a plane at right angles to that in which the dip needle readings are taken.

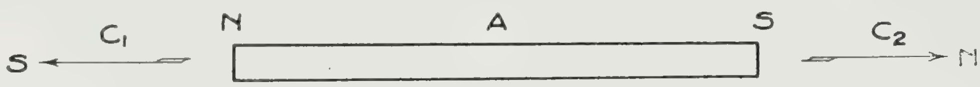


Fig. 40—Bar magnet showing two neutral points, C_1 and C_2, two poles, N and S, and area of balanced forces, A.

Effect of Bar Magnet on Dip Needle

Now if a compensated dip needle is taken and held in the plane of the meridian, somewhat to the south of C_1, there will be a zero reading; but at C_1, there will be a reading of 90°, with the south-seeking pole down (negative attraction). Between C_1 and N, the south-seeking pole will dip toward N, and at N it will again point downwards, giving a reading of 90°. Passing from N to S the needle will dip toward the nearer pole, and at A will be horizontal. At S the reading will be 90°, with the north-seeking pole downwards (positive attraction). Between S and C_2, the needle will dip towards S and will be again vertical at C_2. Beyond C_2, the dip will decrease until the needle reaches a normal field, when it will again take a horizontal position.

Now if the compass is held, or in this case the dip needle, so that the needle swings in a plane at right angles to the length of the magnet, we will find some point to the south of C_1, where the north-seeking pole will point downwards at an angle of 90°. As we approach C_1, the dip will decrease until the needle becomes horizontal. From C_1 to N the south-seeking pole will gradually dip until it becomes vertical over N. From N to A the south-seeking pole of the compass will continue to point downwards, but at A the needle becomes horizontal. Between A and S, the north-seeking pole dips at 90°; but between S and C_2, the dip gradually decreases until it is zero at C_2. To the north of C_2, the dip increases until the normal earth field is reached when it again dips 90°.

Effect of Bar Magnet on Magnetometer

Through the courtesy of Dr. Charles Camsell, Deputy Minister of Mines for Canada, a Thalen-Tiberg magnetometer was available for comparative work. In the area south of C_1, a zero reading was observed as would be expected for a needle that is compensated for the normal earth attraction in the plane at right angles to the magnetic meridian. At C_1 it was also horizontal and acted in the same way as the dip needle when held in this plane. Between C_1 and N the south-seeking pole gradually dipped, becoming vertical at N. At A the needle became horizontal, and as it was carried toward S it again became vertical and after passing S gradually gave lower dip, until at C_2 it was again horizontal and remained horizontal to the north of C_2, as would be expected in the normal earth field.

Measurements by the Three Instruments Necessary in Some Cases

It is shown by this that at C_1 and C_2 magnetic forces neutralize each other so that the compass is apparently useless, while the dip needle appears to indicate a pole; but by turning it to swing in a plane at right angles to the maximum dip, there is obtained a zero reading which utterly disproves the supposition that this is a pole. It will be found, however, that the compass readings show a radiation about this point.

At N and S the 90° dip of the dip needle and inclinator locates these as poles, and the fact that the ordinary compass always points its appropriate pole to these two points makes all three types of compass of value in locating the poles.

At A the compass points so as to be parallel with the magnet, which in this case also indicates the earth's meridian, so that its reading is of no value in locating the magnet. If, however, the magnet is turned we get a compass variation which is of value. At this point, however, the dip needle and inclinator give zero readings. Usually A represents a limited area, but in a multipolar field it may assume considerable size and under such conditions the only indications

of a magnetic body are the compass variation and the zero reading of the dip needle, when used as an inclinator. If at this point a measure of the horizontal intensity is determined by the magnetometer, the compass reading is of value.

It will be seen from the foregoing that neither compass, dip needle, nor inclinator, when taken alone, gives full information at C_1 and C_2, and it is only when the observations with all three are combined that we can recognize the character of these two points. At A the dip needle alone indicates the presence of a magnetic body, except when horizontal intensity is measured.

Between N and C_1 and S and C_2 the dips obtained by both dip needle and inclinator would lead to the supposition that a magnetic body was below, but the compass disposes of that fallacy.

In the area between N and A and in that between A and S any one of the three types of compass will give results.

It will thus be evident that in outlining an ore body by magnetic means it is not always safe to depend on a single instrument and it is desirable to have three measurements for every station. This costs more money, but is probably cheaper than a thousand feet of diamond drilling.

If our bar magnet is held in positions other than the one indicated, certain variations are found in the effects upon all three instruments, but sufficient has been said to show that care must be exercised in making observations and in interpreting results.

Magnetic Properties of Crystals

Further confirmation of the necessity of having magnetic measurements in three planes is obtained from a study of the magnetism displayed in crystals, which have their magnetic properties arranged with the same definite relation to the axes as is shown for other physical properties.

Very little study has been devoted to the extension of the observations on crystals to the investigation of ore deposits. Sufficient is known, however, to show that in dealing with a body that has length, breadth, and thickness, it is necessary to have measurements in three directions.

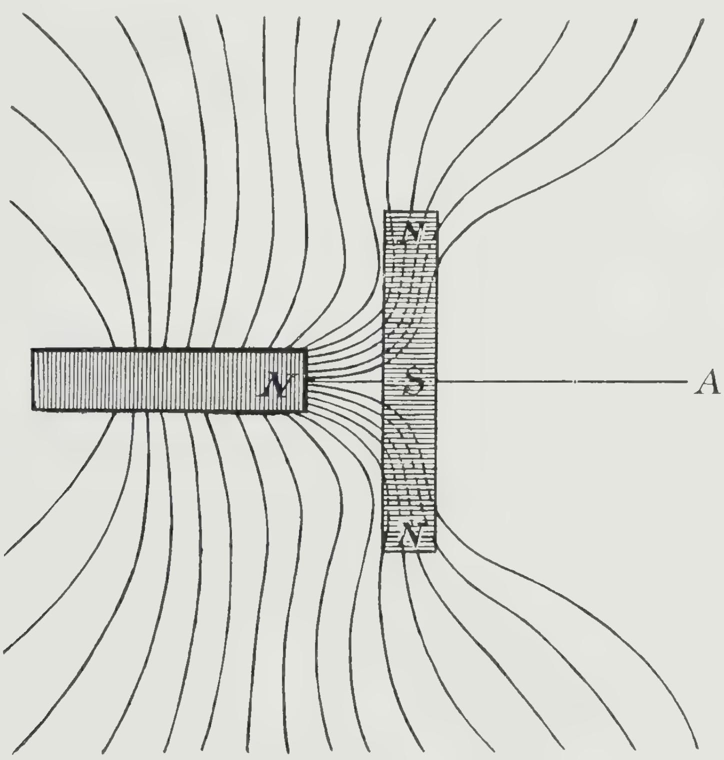


Fig. 41—Induced magnetic field, showing area lacking lines of magnetic force (after Haanel).

Zero Readings

In special cases it has been observed that the dip needle gives zero readings. This occurs where a flat deposit of magnetite dips so that it is at right angles to the normal earth field.[1] So far as the writer is aware no experiments have been conducted to determine the action of the magnetometer over such an ore body, though Haanel shows the same type of field (Fig. 41)[2] and indicates a large area where he states that there are no lines of magnetic force, which would insure a zero reading for the inclinator.

[1]Broderick, T. M., Econ. Geology, Vol. XIII, pp. 35-39.
[2]Haanel, E., op. cit., p. 13.

In case the magnet is curved so that we have the horseshoe type, with the poles at the top, it is at once evident that the dip needle will give zero readings when held between the poles and in the vertical line bisecting the field, but on either side of this line the needle will show a dip with the point of attraction above. This point is of importance in prospecting in a folded region where the poles may be on hills and the main deposit underlies a valley, and emphasizes the necessity of topographic mapping for a final solution of the problem of locating an ore body.

Use of the Instruments by the Prospector

In most instances the first indication of a magnetic ore body will be obtained by noting the variation of the compass, and many such variations are a matter of record in connection with surveys of meridian and township lines. To use the compass as a further help in prospecting is perfectly feasible when used on a picket line. The dial compass, however, permits of fairly accurate determinations of magnetic variation without a picket line and helps to establish a definite magnetic line. Usually the greatest compass variation is slightly north of the ore body, though a deposit striking east and west may in certain instances cause no compass variation.

For the prospector, the dip needle will prove of valuable assistance in locating magnetic areas. It should be borne in mind that the compensation of the needle is such that, with the exceptions already noted, it gives the least dip when held in the plane of the magnetic meridian and points to 90° when held at right angles to this meridian. In some dip needles the compensation is made by a weight below the centre of gravity which may be sufficient to impede the rotation of the needle to the 90° position.

Having located a strongly magnetic band the prospector should search for an outcrop of an iron-bearing formation in or close to this magnetic area. In case the cover is not too deep, it will be necessary to trench if an outcrop cannot be found. When a single outcrop can be located, the strike and dip of the ore body can frequently be determined, and these taken in conjunction with the magnetic readings give great assistance in directing trenching operations. Usually it will be found that the greatest attraction is slightly to the north of the magnetic body, and a second high reading may be obtained still farther to the north at the neutral point. Between the two points of maximum dip, the compass will point in a southerly direction and at the second point it will be sluggish and may point in any direction. Usually no ore will be found between the points of maximum dip. In certain rare cases where the ore body is flat-lying a negative pole may be found, and there may be a 90° dip in a negative direction. Under these circumstances the ore body will lie to the south of the pole, and if a positive pole is found in such a deposit it will lie on or near the southern margin. Such deposits are, however, only exposed by erosion and are readily accessible for prospecting by other means.

Searching for Iron Ore in Depressions in Iron Formation

For rapid reconnaisance work, particularly for deposits that lie under water, the dip needle and compass can be used in a canoe and will quickly show areas of marked attraction, but the detailed survey must be made in winter on the ice and the drilling, if that should prove desirable, will in most cases have to be done in the winter. The Josephine ore body is such a sub-lacustrine deposit, and many other lakes are known where pronounced magnetic attraction has been observed. Such areas should be carefully surveyed, for the most important deposit of oxidized ore in Ontario, the Helen Mine, was located under a lake.

In the writer's experience magnetic attraction has been observed frequently in swamps and on lakes. This is not often shown in transit surveys, as the stations are usually on elevations.

In his discussion of the ore body at the Helen Mine, the writer[1] has demonstrated that the oxidized ore was originally siderite and occupied much less space than the original ore body. In the shrinking accompanying the oxidation, a hollow was formed which filled with water and formed a lake. The drilling of the Josephine has shown another such deposit underlying Parks lake. Whether such deposits are peculiar or are what may be expected in certain depressions in the formations that are associated with iron formation, is a problem that must be solved by diamond drilling after a careful geological, topographical, and magnetic survey. In the writer's experience the bodies of iron ore that outcrop on an elevation have invariably been low-grade, and in his opinion the search for high-grade deposits must be made in depressions along the strike of the formation as determined by the outcrops of lower-grade ore.

Special Readings to be Noted

The location of two points of maximum attraction gives an indication that the pole of the deposit is near the surface, for with deep-seated deposits there will be obtained a resultant of the forces of the earth's field and of the field of the magnetic ore body that will give one position of maximum dip instead of two.

A point of supreme importance in the use of the dip needle is to note the character of the attraction, whether positive or negative. When positive attraction gives place to negative, with an area of no dip intervening, the probability is that the deposit is continuous.

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[1]Ont. Bur. Mines, Vol. XXIV, pt. 1.

This is rendered certain if the dip needle gives zero readings both in the plane of the magnetic meridian and at right angles to it, for the compensation is for the magnetic meridian only. At any other place where a zero reading is obtained in the magnetic meridian, a reading of 90° should be obtained in the plane at right angles to it.

Abnormal Conditions Met with in Magnetic Exploration

Up to the present, it has been assumed that normal magnetic fields are being dealt with, but in practice we frequently find abnormal conditions. As a result of faulting the two arms of a syncline may result in a multipolar deposit. No general rules can be given for such a case. Each deposit furnishes a separate problem.

Even where we have comparatively simple conditions the formation is frequently so tilted that only one of the poles is effective, and an almost complete lack of magnetic data results when the deposit is flat and perpendicular to the normal earth field.

Experience on Lake Superior Iron Ranges

In considering the application of magnetic measurements to iron ores other than magnetite, it is to be noted that all the common ores are weakly magnetic and are good conductors. Frequently they contain sufficient magnetite so that good results can be obtained by a magnetic survey. The possibility of locating a body of pure hematite is, however, more problematical, though if magnetite occurs in some part of the deposit information of value may be obtained.

Hotchkiss[1] states that, "In the Lake Superior region it is generally true that magnetic attractions of *very great strength* are not found immediately over large bodies of hematite. There are some notable exceptions to this, such as the Chapin mine at Iron Mountain, but it is believed that the statement will hold true in a large majority of cases. *However, there is no iron range in the Lake Superior district which does not show at least mild attractions on or near the iron formation. These attractions have been in nearly every case of much value in delimiting the range and indicating favourable places to explore.*"

The writer has in a single case observed a pole in a siderite deposit.

Relation of Magnetic Survey Lines to Ore Body

The results of a magnetic survey will show an area which in the case of tilted rocks will be long and narrow. By some it is called a magnetic line. Near this line will be the more favourable place for locating drill holes, and at this stage a knowledge of the geological structure decreases the element of chance in locating ore, for this magnetic line is dependent upon the size of the ore body and its depth below the surface. Its position with respect to the ore body is also dependent on the dip of the ore body, and before drilling every means should be employed to ascertain this. If the ore body dips to the north the magnetic line will probably overlie the deposit. If the dip is vertical the line will be either directly over the deposit or somewhat to the north. If the formation dips to the south the magnetic line will in most cases be to the north of the deposit so that all drill holes must be located south of this line.

In case the deposit is deep-seated and no information regarding the dip and strike of the rock is available, this information must be obtained by drilling, in which case two holes from one station will give the information, provided one of the holes is vertical.

In drilling the first hole it is desirable to get all possible geological data such as sequence of rocks and the dip, and if ore is encountered the hole should be continued into the underlying rock so as to determine its character. Every dollar so spent will be saved by the recognition of these formations in later holes, for if one of the later holes is started in a formation that is below the ore body, it can be immediately discontinued. In general, vertical holes will be found to give the most information.

In a drift-covered area the striking of ore in the first hole is an accident, even with the best information that can be obtained, but with the increased information available with each hole drilled, the chances of finding the magnetic body are rapidly increased.

Use of the Magnetic Surveys

In summing up, magnetic surveys to give the most reliable data should involve compass, dip needle, and magnetometer readings. A magnetic map without compass bearings, or horizontal intensity, is of little value and will lead to the condemnation of good deposits. The geological structure should be known before the final interpretation is made, and the influence of high hills of magnetic and non-magnetic material on the magnetic field should be known. In the prospecting stage, certain magnetic ores can be roughly determined by any or all of the instruments. To prepare for drilling operations requires an interpretation by a man who has made a special study of the subject as a whole. It must also be borne in mind that the location of a magnetic body by magnetic means gives no indication of the iron content. This can only be determined by opening up the ore body by trenching or drilling. Money must be spent for this, but unlikely locations may be eliminated by a thorough magnetic survey. The most important factor of all, however, is the retaining of a competent man to interpret the magnetic maps and correlate these with the other geological data so that drill holes may be located with the greatest chance of striking ore.

[1]Op. cit., p. 85.

5. METALLURGY OF IRON AND STEEL

By Owen W. Ellis

Iron

The extraction of iron from the ore is effected in a furnace which is essentially a vertical shaft, and which is first completely charged and subsequently replenished with predetermined quantities of ore, limestone, and fuel. The process of extraction is continuous; solid material is charged at the top of the shaft, and liquid slag and iron are at intervals removed from the furnace through openings situated near the base of the shaft.

The extraction of iron from the ore implies not merely the reduction of metal from the oxides in the ore, but also the separation of the metal so reduced from the siliceous and aluminous gangue.

The reduction of iron from the ore is mainly effected by carbon monoxide. The carbon monoxide is formed as a result of the combination of oxygen with the carbon of the fuel charged. The oxygen is supplied in the form of air which, heated and under pressure, is introduced through openings (tuyères) in the periphery of the shaft at a point just above the crucible wherein the liquid products of the operation collect.

For the separation of iron from the ore it is essential that there be charged into the furnace a quantity of flux (limestone) sufficient to unite with the gangue of the ore to form a free-running slag and that a temperature be maintained in the furnace sufficient to hold the slag in a fluid state.

The proportions of the elements which pass from the charge into the liquid metal are dependent upon a variety of factors.

The carbon content of the iron is determined mainly by the amount of carbon in and the temperature of the crucible of the furnace. It is known, in a general way, that a large quantity of carbon and high temperatures in the crucible contribute to a high carbon content in iron, and vice versa.

The silicon content of iron is largely determined by temperature and slag composition.

The higher the temperature of the furnace, which itself is dependent on the fuel content of the charge and the temperature of the blast, and the less basic the slag, the greater will be the silicon content of the iron.

Other things being equal, the higher the manganese content of the charge, the greater will be the manganese content of the iron.

It is almost always desirable that the sulphur content of the iron be reduced to a minimum. The main source of this element is the fuel. Sulphur exists as calcium sulphide in the slag, and to keep it there it is essential that the slag be of a basic character. The introduction of manganiferous ores into the charge is also of value in limiting the sulphur content of the iron.

Under normal conditions of working, all the phosphorus of the charge will enter the metal. When an iron of low phosphorus content is required, ores of low phosphorus content must be used.

CARBON

The carbon in cast iron may be present in two forms. It may exist in combination with iron in the form of iron carbide (Fe_3C), a compound to which the name "cementite" is almost universally applied. This compound (Fe_3C) gives the white irons their characteristic appearance. Carbon may also occur in the form of graphite, uncombined. The presence of graphite is the prime cause of the grey fracture of foundry irons.

Other things being equal, the greater the total carbon content of iron, the greater will be its fusibility, and the less will be its $\frac{\text{cementite}}{\text{graphite}}$ ratio.

The total carbon content of iron as it comes from the blast furnace varies from about 2.75 to 4.25 per cent. That of cast iron, obtained by remelting pig iron in the foundry, averages about 3.25 per cent., rarely falling below about 3 per cent. or exceeding about 3.75 per cent.

The physical and mechanical properties of cast iron are almost entirely dependent upon its $\frac{\text{cementite}}{\text{graphite}}$ ratio. Foundry practice consists largely in the control of this ratio, which tends to decrease under the following conditions:—

1. As the total carbon and silicon contents of the iron are increased,
2. As the sulphur and manganese contents of the iron are decreased,
3. As the rate of cooling of the iron from the fluid state is decreased, and
4. As the temperature of the solid alloy is raised (the temperatures necessary to effect a reduction in the $\frac{\text{cementite}}{\text{graphite}}$ ratio at a measurable rate are in excess of about 750° C.). The rate at which the ratio is reduced varies directly with the temperature and the time of annealing.

A decrease in the $\frac{\text{cementite}}{\text{graphite}}$ ratio of iron results, within limits, in a decrease in its density, hardness, shrinkage, and chilling power, and an increase in its machineability.

The strength of cast iron is almost independent of the $\frac{\text{cementite}}{\text{graphite}}$ ratio. It is determined partly by the combined carbon content of the iron and partly by the form and distribution of the graphite.

Other things being equal, an increase in the combined carbon content of iron to about 0.80 to 1.00 per cent. will result in an increase in its tensile strength. If this content of combined carbon is exceeded, a reduction in strength ensues, which terminates only when the carbon is entirely in the form of graphite.

The graphite in grey cast iron occurs in the form of minute plates. These plates are sometimes flat, but usually are concave.

In surfaces of cast iron that have been exposed, polished, and finally subjected to microscopic examination, traces of these plates appear as lines or as arcs of circles (approximately). In certain grades of iron, these graphite plates are small and slender. In other grades they are large and coarse. In Figs. 42 and 43 are shown, under the same magnification, photomicrographs of two samples of iron, which serve to show how great may be the variations in the character of graphite in cast iron.

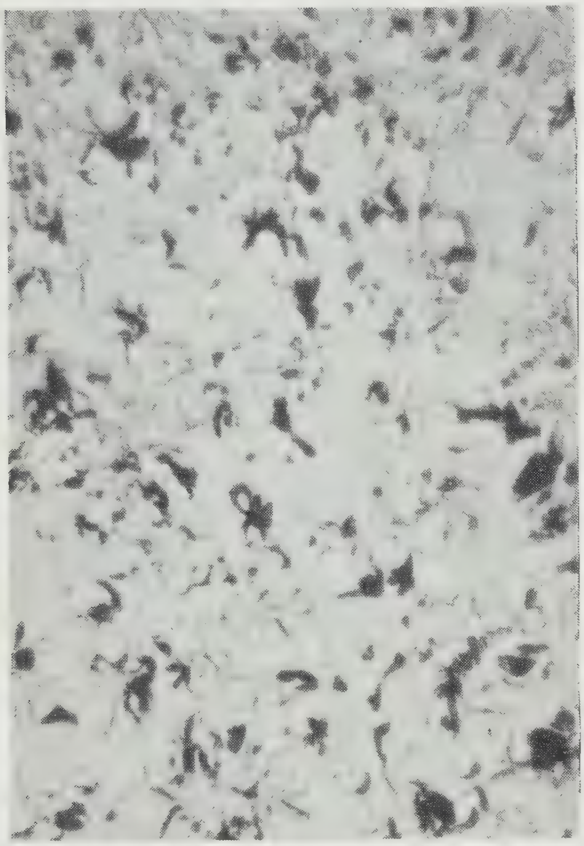


Fig. 42

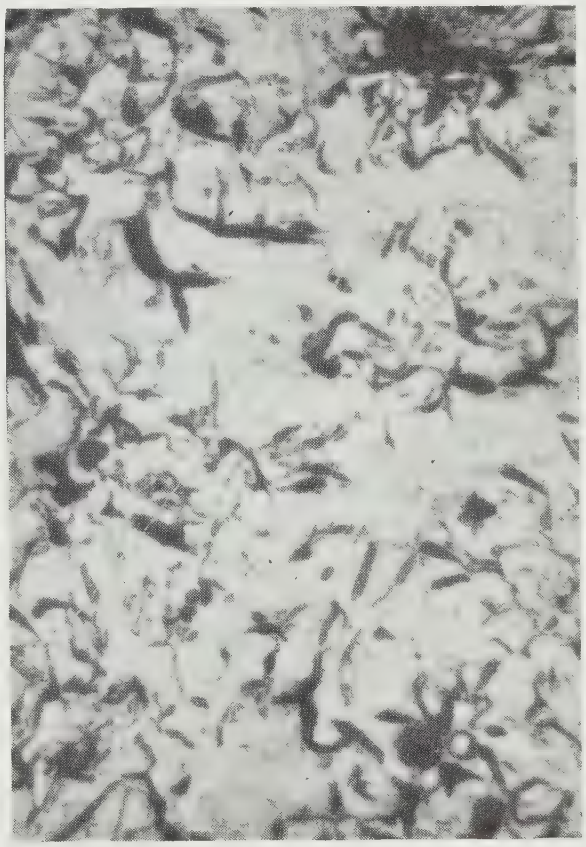


Fig. 43

Grey cast iron, unetched, showing differences in character and distribution of graphite flakes—magnification, 100 diameters.

Other things being equal, the coarser the graphite plates the weaker will be the iron.

The influence of the $\frac{\text{cementite}}{\text{graphite}}$ ratio upon the mechanical properties of iron is nicely manifested by the results of tests by Dr. Stead, who found that an increase of 0.10 per cent. of graphite may reduce the transverse strength of cast iron by about 225 pounds and the tensile strength by 1,800 pounds per square inch.

The fact that the tensile strength of cast iron reaches a maximum when its combined carbon content is in the neighbourhood of 0.90 per cent., and that this percentage of carbon is about that of the strongest steel, has given rise to the suggestion that the grey cast irons may be considered as steels wherein graphite is disseminated in the form of plates such as have already been described. This opinion has been amply confirmed by the microscopic examination of grey cast irons, which have been found to consist of a matrix of steel of the combined carbon content of the cast iron, wherein have been generated planes of weakness as a result of the deposition of carbon in the form of graphite plates.

At one time pig iron was graded by fracture. A relationship, unfortunately of no well-defined character, was known to exist between the fracture of iron and its chemical and mechanical

properties. Later it was discovered that the fracture of cast iron was to some extent determined by its total carbon content, and to a large extent by its $\frac{\text{cementite}}{\text{graphite}}$ ratio. It has been shown above that this ratio is dependent upon a host of variables. The fracture of cast iron could at the best, therefore, be but a fickle guide to a knowledge of the chemical and mechanical characteristics of a given sample of pig iron. It may be said, however, that in a general way, as the total carbon content of iron and as its $\frac{\text{cementite}}{\text{graphite}}$ ratio decreases, the fracture of iron changes from an open grey, in which the plates of graphite through which rupture of the iron has proceeded are so large as to be clearly visible to the naked eye, to a coarse grey, from a coarse to a finer grey, from a finer grey to a close grey, from a close grey to a white dappled with grey (mottled), and from a mottled to a white.

SILICON

The $\frac{\text{cementite}}{\text{graphite}}$ ratio of iron tends to decrease as the silicon content of iron is increased. The reaction whereby Fe_3C is changed into $3Fe+C$, which ensues as a result of the addition of silicon to iron, is generally referred to as graphitization. Silicon varies from 0.20 to 4.00 per cent. in cast iron, but rarely exceeds 3.50 per cent. or falls below 0.50 per cent. It is present in cast iron in the form of iron silicide, dissolved in the pure iron of the alloy, which within limits it tends to render hard and strong.

The addition of silicon to iron results, within limits, in a decrease in its density, hardness, shrinkage, and chilling power, and an increase in its machineability.

The addition of silicon to white iron results in an almost proportional decrease in the chilling power of the resulting alloy up to a limit of 1 per cent.

The hardening effect of iron silicide is sometimes noticeable when the silicon content of iron exceeds about 2 per cent. Hence it occasionally happens that iron relatively hard to machine is improved by a reduction of its silicon content.

The approximate proportion of silicon required in cast iron for various purposes has been given by Howe as follows:—

	Silicon, per cent.
Thick (hence slow cooling) castings, machinery castings	1.50 to 2.25
Thin (hence fast cooling) castings, ornamental castings	Up to 3 or even 3.4
Radiators and castings of similar character which require density of structure and a low content of graphite	1.00 to 1.75
Car wheels, which require that the $\frac{\text{cementite}}{\text{graphite}}$ ratio may be readily controlled by chilling[1]	0.50 to 0.80

MANGANESE

Manganese is an important constituent of cast iron on account of its affinity for oxygen and sulphur. Such manganese as is present in a furnace (cupola or reverberatory) charge, will tend first to react with such oxides as enter the iron (forming oxide of manganese, MnO, which combines with silica, SiO_2), and then to unite with such sulphur as is present in the metal (forming manganese sulphide, MnS). The manganese silicate ($MnO.SiO_2$) enters into and forms part of the slag which floats upon and covers the molten metal, whether in the furnace or the ladle. The manganese sulphide (MnS), on account of its relatively low specific gravity, tends to disengage itself from the molten iron. If the temperature of the iron be high and the time for separation be sufficient, a fairly complete removal of manganese sulphide from the iron may be effected. The manganese sulphide, under these circumstances, forms a layer between the molten metal and the molten slag. If the conditions are less satisfactory than have been described, some manganese sulphide will accumulate in the upper layers of the liquid metal. In castings made from such contaminated iron, the sulphide may cause serious trouble in machining; in any case its presence conduces to brittleness, or, in other words, a low resistance to shock.

Such manganese as is in excess of that which combines with oxygen and sulphur, will unite with carbon to form manganese carbide (Mn_3C) which, entering into solution in the iron, acts in the manner which has already been described. Manganese is generally considered to retard graphitization. This is true, but this effect does not evidence itself until the manganese content is well above that usually present in foundry irons. Hence, though the hardness of iron is increased by the addition of manganese, the cause is not usually the retention of carbon in the form of cementite. Manganese increases the shrinkage of cast iron. The manganese content of good castings generally varies between 0.40 and 0.70 per cent. That of chilled car wheels varies between 0.15 and 0.30 per cent.

SULPHUR

Sulphur tends to restrain the graphitization of cementite. On this account it increases the shrinkage and chilling power of cast iron. It may, therefore, be termed a hardening agent. This element should, however, be employed with great caution, if at all, in this capacity on account of the objectionable effects accompanying its use.

[1]The tread of the wheel requires to be hard, the body of the wheel relatively tough.

The presence of sulphur renders molten iron thick and sluggish. Sulphurous iron, therefore, requires to be poured at as high a temperature as possible if castings free from blowholes are to be obtained.

Silicon and manganese may be employed to counteract the ill effects of sulphur.

Silicon, on account of its tendency to promote graphitization, resists the effect of sulphur in holding carbon in combination; it does not remove sulphur, nor does it prohibit the shrinkage due to sulphur or reduce the tendency of sulphurous irons to crack.

Manganese reacts with iron sulphide, with consequent formation of manganese sulphide and liberation of iron.

$$FeS + Mn = MnS + Fe.$$

Manganese sulphide can be removed from iron, as has been shown above. Even when it is not removed, its presence in cast iron is fraught with far less serious consequences than is that of iron sulphide.

Sulphur is frequently limited by specification to 0.05 per cent., but in the hands of experienced and careful founders as much as 0.20 per cent. can be allowed in certain irons without ensuing unsoundness. In thin castings needing great fluidity, the sulphur content should be reduced to 0.05 per cent., while if castings are to be soft enough for machining the sulphur should not exceed 0.08 per cent.

PHOSPHORUS

Phosphorus combines with iron to produce a phosphide, Fe_3P, which with iron forms a eutectic, the presence of which effects a marked increase in the fusibility and decrease in the total carbon content of iron. Phosphorus is chiefly of value in increasing the fluidity of iron.

As the phosphorus content of cast iron is raised to about 0.4 per cent., so is the strength of the cast iron enhanced. Further additions of phosphorus appear to have but slight effect on the strength of cast iron until the percentage reaches about 0.75 per cent. Above this point the alloys are liable to be brittle, and unless fluidity is more important than strength, 0.75 per cent. of phosphorus should not be exceeded. For thin castings in general, which are not required to be strong, the phosphorus can be increased to 1.5 per cent. or more, but in thin castings such as automobile cylinders, which are required to withstand wear and tear, not more than 0.30 per cent. of phosphorus should be allowed, owing to the slight tendency towards segregation of high phosphide irons. When much manganese or sulphur is present in the iron, or if the castings are thin and hence cool rapidly, so that graphitization is retarded, the phosphorus content must be reduced.

MALLEABLE CASTINGS

A somewhat specialized use of cast iron is found in the manufacture of malleable castings. Two malleablizing processes are generally recognized, and the material used is common to both processes. It is white cast iron. The compositions recommended as most suitable for the two processes of manufacture by the Committee of the Iron and Steel Institute for Foundry Practice (1917) are as follows:—

Type of castings	European process			American process		
	Heavy	Medium	Light	Heavy	Medium	Light
	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.
Total combined carbon	2.8 to 3.5	2.8 to 3.5	2.8 to 3.5	2.8 to 3.5	2.8 to 3.5	2 8 to 3.5
Silicon	0.5 to 0.7	0.6 to 0.8	0.7 to 0.9	0.4 to 0.6	0.6 to 0.8	0.8 to 1.0
Manganese		Up to 0.15			Not over 0.40	
Sulphur		Not over 0.35			Not over 0.07	
Phosphorus		Not over 0.20			Not over 0.20	

Castings that are to be malleablized rarely exceed 1 inch in thickness. This limit in thickness is enforced by the necessity of restraining graphitization by the rapid cooling of the castings, wherein the presence of graphite must be avoided. The structure of an iron prior to malleablizing is shown in Fig. 44. The carbon present in the alloy is entirely in the form of cementite.

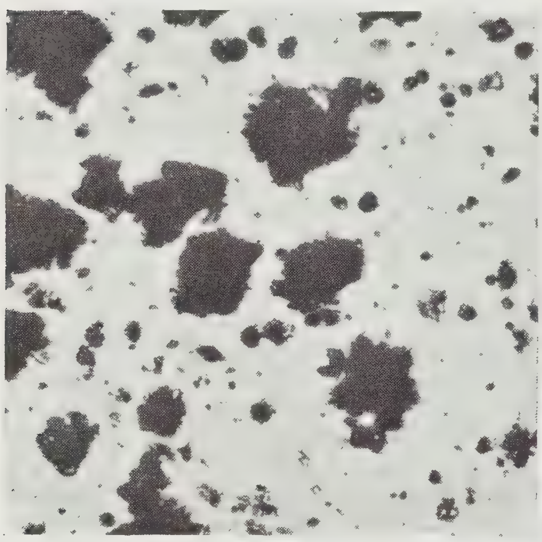
The extremely brittle white iron castings used in these processes are rendered malleable either by removing part of their carbon by annealing them under strongly oxidizing conditions (close-packed in iron oxide)

$$3\ Fe_2O_3 + C = 2\ Fe_3O_4 + CO$$

or by graphitization of the cementite, which is also effected by annealing. The graphitization of cementite results in the precipitation of graphite in the form of "temper" carbon (Figs. 45 and 46).

Unless annealing of white iron is conducted under neutral or reducing conditions, both graphitization and oxidation ensue. In the American process graphitization is what is aimed at; in the European process oxidation is the goal. The products of the former process are referred to as "black heart malleable castings," and are possessed of the structure shown in Fig. 45, while

Fig. 44—White cast iron for malleablizing—magnification, 100 diameters.



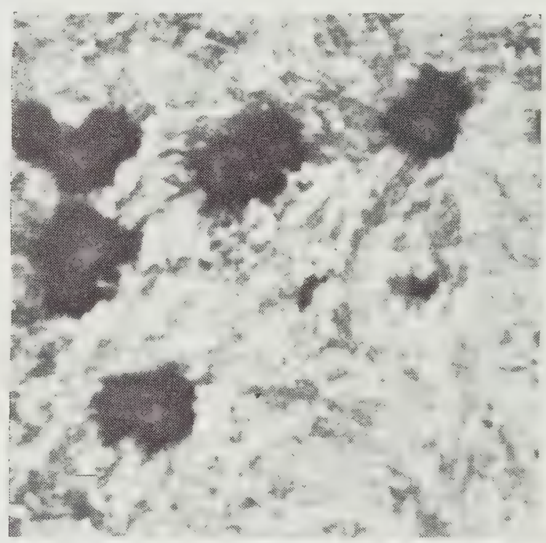


Fig. 45—American malleable. Fig. 46—European malleable.
Magnification, 100 diameters; Illumination, vertical.

those of the latter process are known as "white heart or steely malleable castings," and are possessed of the structure shown in Fig. 46. Black heart annealing is conducted at temperatures of from about 770° C. to 840° C., the annealing temperature being dependent on the composition of the iron. White heart annealing is conducted at temperatures varying from 840° C. to 880° C.; these too are influenced by composition. The time of exposure to the maximum temperature varies in very thin work to very heavy work from a few hours to a few days.

WROUGHT IRON

At one time the most important product of the conversion of pig iron was wrought iron. Wrought iron may be described as a malleable iron which has been aggregated from pasty particles of iron without subsequent fusion. It generally contains so little carbon that it approaches pure iron in its characteristics.

Commercial wrought iron is still manufactured, usually by what is known as the "puddling" process. The puddling process consists in the application of a number of oxidizing reactions, whereby the impurities of the pig iron that form the basis of the process are removed. The pig iron for the process is preferable when it shows the following analysis:—

	per cent.
Carbon	3.5
Silicon	1.5 to 2.0
Manganese	0.8
Phosphorus	1.0

Other elements are considered as impurities and are, therefore, kept as low as possible. The use of too pure pig iron involves high cost of process, less weight of product, and frequently an unsatisfactory iron (hot short).

Oxidation of the carbon, silicon, manganese, and phosphorus of the pig iron is effected by causing the pig iron to melt down into a fluid bath of slag holding in solution oxide of iron which reacts with the elements referred to above and effectively removes them. The direct action of the oxygen of the air is small and may lead to a waste in iron. The process of oxidation is effected in a furnace of the reverberatory type, the temperature within which at the conclusion of the process is less than the freezing point of iron. As a result the metallic product of the operation, almost pure iron, is at its conclusion in a pasty condition. Entrapped in this iron are particles of slag which remain permanently entangled in the metal unless it is subsequently fused. These slag particles are compressed or elongated when the iron is deformed, and sections of wrought iron rod taken in the direction of rolling exhibit the characteristic structure of Fig. 47. In this photograph are to be seen the sections of crystals of almost pure iron and of the elongated particles of slag which were entangled in it during the puddling process.

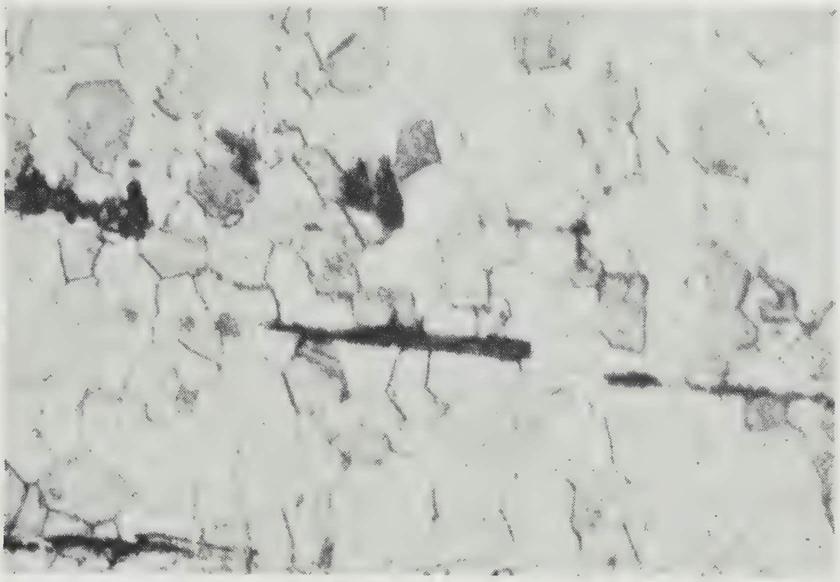


Fig. 47—Wrought iron. Longitudinal section of bar showing influence of rolling on orientation of slag in groundmass of ferrite—magnification, 100 diameters.

Steel

Of the modern methods of making steel, the open-hearth, converter, electric, and crucible processes are the most important.

Open Hearth

By far the largest output of steel results from the use of the open hearth furnace, which is of the reverberatory type. The furnace hearth is shallow and is usually elliptical in plan. For the fusion of the furnace charge heat is derived from the combustion of producer gas and air, both preheated by passing them through regenerators. Temperatures as high as 1700° C. may be obtained as a result of the employment of correctly designed furnaces and regenerators.

The furnace hearth may be lined with either acid or basic refractories.

The raw materials used in the open hearth process include pig iron, scrap iron, scrap steel, ore, scale, carbon, lime, limestone, fluorspar and other fluxes, spiegeleisen and other ferro-alloys. Pig iron may be charged either in the liquid or the solid state; scrap iron and steel are always added in the solid state. The composition of the charge is determined by the nature of the hearth, by economic conditions (such as the price of scrap, etc.), and by the methods of melting and refining employed.

In acid practice the furnace hearth is lined throughout with siliceous materials, e.g., silica sand. The charge is characterized by its relative freedom from sulphur and phosphorus, the removal of which in the acid process is difficult to accomplish.

In basic practice the furnace hearth is lined throughout with basic materials, e.g., calcined dolomite, sometimes mixed with a little pitch or tar. The charge may contain relatively large proportions of sulphur and phosphorus, the removal of which is effected in the basic process by the addition of lime or limestone to the melt.

The open hearth process may be considered as occupying three distinct periods. During the first of these periods, complete fusion of the charge ensues; during the second, oxidation of carbon, silicon, and manganese, and in the basic process, removal of sulphur and phosphorus from the melt occurs; and during the third, refining of the steel resulting from the earlier operations is effected.

In the acid process pig iron and scrap are generally charged. The iron and scrap are so introduced into the furnace as to avoid injury to the siliceous hearth as a result of the slagging action of the iron oxide that inevitably forms during fusion of the charge. In the basic process, pig iron (preferably molten), scrap, ore, and limestone are charged, no restrictions being placed upon the phosphorus content of the constituents of the charge. The precautions necessary in acid practice to avoid slagging of the hearth by iron oxide are, for obvious reasons, avoided in basic practice.

In both processes partial removal of carbon, silicon, and manganese from the charge is effected during the fusion. The almost complete elimination of manganese is frequently effected during the first period. Silicon is at the same time partially removed.

Further removal of carbon, silicon, and manganese, can only be obtained by treatment of the charge with iron oxide (ore and scale). This treatment occupies the second period of the open hearth process. In basic practice concurrent removal of phosphorus and sulphur from the melt is effected by treatment of the same with lime or limestone.

The elimination of carbon may be halted when the carbon content of the melt is that required in the finished steel. Then, after addition of ferro-manganese and ferro-silicon to the melt, the furnace may be tapped and the finished steel removed. In basic practice the manganese and silicon additions are usually made in the ladle. These additions are necessitated by the oxidized condition of the melt, both the manganese and the silicon acting as deoxidizers. The manganese is also of value on account of its effect, first, in reducing the harmful effects of the sulphur present in the steel, and, second, in refining the grain of the steel.

In the production of high-grade steel the second period, that of oxidation, is followed by that of refining. During the second period a very rapid removal of carbon is at first effected. The subsequent removal of carbon is conducted at a somewhat slower rate, and during the third period, that of refining, the removal of the last few "points" of carbon may occupy an hour or more. At the conclusion of the refining period, the oxides are practically eliminated from the steel, having been absorbed in and retained by the slag. At the same time the carbon content of the steel has been reduced to a minimum. Deoxidation of the melt is scarcely needed; nevertheless, additions of ferro-manganese and of ferro-silicon are usually made. The required carbon content is obtained by adding to the steel, either in the furnace or the ladle, pig iron, coal, or coke.

Converter Process

In the converter process, due to Bessemer (1855), air is blown through molten pig iron, and as a result carbon, silicon, and manganese are almost entirely eliminated by oxidation.

The converter process involves the use of a pear-shaped vessel known as a "converter." This vessel is mounted on trunnions so that it can be tilted for charging, and for pouring, etc. When the vessel is inclined, the tuyères, through which air is admitted to the vessel, come above the surface of the metal; hence, on cessation of the blast, the danger of metal flowing into the tuyères is counteracted. Air is supplied at a pressure of from 20 to 30 pounds per square inch, a pressure that is sufficient to force the air through the molten metal when the vessel is erected.

The converter may be lined with acid material (siliceous) or with basic material (calcined dolomite). The original process involved the use of an acid lining and is on this account referred to as the acid Bessemer process. The basic Bessemer, or Thomas, process to eliminate phosphorus from pig iron in the converter, involves the use of a basic lining.

The two processes are similar in many respects. In both the converter is first heated, either as a result of previous operations or by means of a coal or coke fire fanned by the blast. Into the hot vessel there is then introduced molten pig iron from the blast furnace, cupola, or mixer. In basic practice from 300 to 400 pounds of lime per ton of metal to be blown is thrown into the vessel prior to the addition of the molten iron.

Once the metal is charged, the blast is turned on and the vessel erected.

A short flame, accompanied by showers of sparks, issues from the mouth of the vessel at the moment the blast encounters the liquid iron. This flame increases in volume as the temperature of the charge rises, and evidence of vigorous reaction within the vessel is given by the ejection from the converter of large drops of molten slag and metal.

The appearance of the flame, the violence of the "boil" (reaction), and other characteristics of the blow at this stage, determine whether the heat being evolved is in excess of that required for the successful issue of the process. If the metal is "hot," addition of cold scrap is made.

The "boil" lessens in intensity as the blow continues. At the same time the flame contracts and then disappears almost entirely. The "drop of the flame" marks the almost complete removal of carbon from the charge.

The blow occupies from 8 to 15 minutes. At this stage a marked difference in practice is to be observed between the two processes.

In the acid Bessemer process the vessel is inverted, and to the decarburized melt additions of ferro-manganese, or spiegeleisen, and of pig iron are made to give to the metal the desired composition. The addition of manganese to the melt is, in most if not all cases, essential.

In the basic Bessemer process, the blow is continued for some minutes after the flame has dropped. During this "after blow" the phosphorus is mostly removed. It is necessary on many occasions to add more lime to the bath during the "after blow," the length of which is determined by such factors as the composition and the temperature of the metal.

When the blower is satisfied that the steel is of good quality, the vessel is inverted, the slag is removed, and the necessary additions of ferro-manganese and of pig iron are made.

The steel in both the acid and the basic processes is poured from the vessel into the ladle and finally turned into moulds.

The Electric Furnace

There are numerous types of electric furnace used in the production of steel. In all, the heating effect of the electric current is used to maintain the slag and metal in a fluid state within the furnace while the necessary reactions between these two essential constituents of the melt, slag and metal, proceed.

The electric process most frequently consists in the fusion of cold scrap which, when melted, is first subjected to the action of a basic oxidizing slag. This slag is high in lime, and by its means dephosphorization of the metal is effected. When the phosphorus content of the metal has been sufficiently reduced this basic slag is removed and, prior to the introduction of the desulphurizing and deoxidizing slag which is next formed, the necessary additions of carbon, manganese, etc., are quite frequently made. The removal of sulphur and the deoxidation of the metal are partially effected by the addition of ferro-manganese and ferro-silicon to the metal, the manganese combining with the sulphur to form manganese sulphide, and the silicon combining with iron oxide to form iron silicate. The elimination of sulphur is effected more perfectly, however, by the formation of a slag largely composed of silicate of lime. This slag, reacting with sulphur, effects its removal from the molten metal in the form of calcium sulphide. By careful operation, the phosphorus and sulphur contents of the charge may be reduced to exceptionally low proportions and steel of remarkable purity thus obtained. In no other type of furnace is it possible to make heat entirely from scrap metal such, for example, as steel and iron turnings, nor does any other process offer such possibilities in purification as does the electric process.

Crucible Steel

The manufacture of steel by the crucible process involves the fusion in crucibles either of blister steel or of mixtures in suitable proportions of iron or steel with charcoal or cast iron. The higher grades of "cast steel," such as should be used for tools, are made by the fusion of blister steel, sometimes of a carbon content slightly in excess of that required in the finished product.

The melt is brought to the required analysis by the addition of a small proportion of high-grade scrap of somewhat lower carbon content. Inferior grades of crucible steel are made from mild steel scrap of open hearth and converter origin. These products, however, cannot compare with those made from the material described above.

The details of the manufacture of steel by the crucible process need not be entered into here. Sufficient has been said to make it clear that if the raw materials employed in this process are devoid of impurities, the finished product will be characterized by a like freedom, provided, of course, that fusion of the charge has been carried out under conditions which have precluded the entrance of impurities into the crucible during the melting of the charge. In the higher grades of crucible steel, elements other than carbon rarely exceed in amount the proportions given below:—

	per cent.
Silicon	0.20
Manganese	0.35
Sulphur	0.02
Phosphorus	0.02

Composition and Properties of Steel

It will have been gathered from the above discussion that steel is essentially an alloy of iron and carbon to which proportions of silicon and manganese are intentionally added and in which sulphur and phosphorus are present as impurities.

The maximum proportions of the elements present in commercial carbon steel are about as follows:—

	per cent.
Carbon	1.50
Silicon	0.30
Manganese	1.00
Sulphur	0.08
Phosphorus	0.08

As to the reliability and quality of the steel produced by the processes above described, no hard and fast rule can be given; so much is dependent upon the skill exercised in conducting the operations involved in these processes. Speaking generally, however, the reliability and quality of carbon steel varies in order of decreasing excellence in the following manner:

1. Steel made by the crucible process.
2. Steel made by the electric process.
3. Steel made by the acid open hearth process.
4. Steel made by the basic open hearth process.
5. Steel made by the acid Bessemer process.
6. Steel made by the basic Bessemer, or Thomas process.

The cost of manufacturing steel by the electric and crucible processes militates, however, against their extensive use in general engineering work.

Comparing acid steels with basic steels, it is widely admitted that under general conditions of working the former are the more reliable. Assuming that pig iron of the required quality is used in the acid process, the risk of obtaining high phosphorus steel is completely eliminated. However great is the care of the furnace man, there is yet a risk in basic practice that the product will be insufficiently dephosphorized. This danger is more appreciable as the carbon content is increased, since recarbonization of the melt frequently leads to its rephosphorization (phosphorus being reduced from the slag). In the manufacture of dead-soft steel the danger of rephosphorization is small. In respect of sulphur and its removal, the basic processes are at an advantage in respect to the acid processes; though removal of sulphur in basic practice is somewhat erratic, removal of sulphur is always effected to some extent. As to the control of carbon content, the acid process (open hearth in particular) is more desirable than the basic process, since in the latter case recarbonization of the melt must be effected outside rather than within the furnace.

Where high-grade pig, ore, and scrap are used in the basic open hearth, the superiority of the basic process over the acid process is unquestionable.

Comparing converter steel with open hearth steel, there is no doubt that the quality of the latter is higher than that of the former. In the first place, a better control of operations is possible in the open hearth process. In the second place, there is less risk of super-oxidation of the melt in the open hearth process.

The mechanical properties of annealed carbon steels are dependent on a number of factors. Of these, the most important are: method of manufacture and chemical composition.

That the method of manufacture of steel may determine, to some extent, its mechanical properties, has been demonstrated on numerous occasions. Harbord was probably the first to show this clearly. The following table, based on his results, will serve to indicate the influence of the process of manufacture upon the character of steel:—

Tensile strength	Carbon Content of Steel			
	Acid Bessemer	Basic Bessemer	Acid open hearth	Basic open hearth
Lbs. per sq. in.	per cent.	per cent.	per cent.	per cent.
56,000	....	0.14	0.11	0.12
67,200	0.14	0.17	0.18	0.25
78,400	0.25	0.27	0.34	0.36
89,700	0.35	0.39	0.41	0.43
100,800	0.43	0.46	0.48	0.51
112,000	0.50	0.52	0.56	0.59

This table directs attention to the fact that the strength of steel of a given carbon content is dependent upon its mode of manufacture. Speaking generally, open hearth steels are softer than converter steels, and basic steels are softer than acid steels.

The above table also demonstrates the influence of carbon upon the strength of steel. It will be seen that increase in carbon content is in every case accompanied by increase in tensile strength. It is also found that manganese, silicon, etc., are somewhat similar to carbon in their effect upon the strength of steel.

The strengthening effect of carbon changes with the proportion of carbon present in the *pure* iron-carbon alloys. It ranges from 875 pounds per square inch to 1,150 pounds per square inch for each 0.01 per cent. of carbon between the limits 0.00 and 0.70 per cent. The maximum stress of *commercial* steels (untreated) is raised on the average by about 1,000 pounds per square inch for each 0.01 per cent. of carbon up to 1.00 per cent. The ductility of untreated steel in terms of percentage elongation on 2 inches is reduced by about 0.35 per cent. for each 0.01 per cent. increase of carbon content.

From a microstructural point of view, the steels may be considered as divided into two classes; those containing less than about 0.85 per cent. of carbon (mild and medium carbon steels) and those containing more than about 0.85 per cent. of carbon (high carbon or tool steels). Steels of the former class consist of two constituents: ferrite (almost pure iron holding silicon, etc., in solid solution), and pearlite (an intimate mixture of ferrite and carbide of iron, Fe_3C, cementite). The photomicrographs of Figs. 48 to 50 show the uniform increase in the amount of pearlite in these steels that ensues on increase of their carbon content. The 0.85 per cent. alloy consists almost entirely of pearlite. Steels of the latter class consist of the two constituents, pearlite and cementite. The photomicrographs of Figs. 51 and 52 show the proportions of cementite in alloys containing from 1.2 to 1.5 per cent. of carbon.

The presence of pearlite in steels confers upon these alloys the most important property of increasing in hardness when rapidly cooled from above certain critical temperatures, which are dependent mainly upon the composition of the steels. With certain critical rates of cooling

from above these critical temperatures, full hardness may be obtained. The hardening power of steel is almost directly proportional to its carbon content.

The addition of silicon to *pure* iron has but little effect upon its ductility. The tenacities of the alloys of iron and silicon, however, are slightly in excess of that of iron, the increase in maximum stress per 0.01 per cent. silicon being about 125 pounds per square inch for alloys annealed at 970° C. Silicon in the proportions usually present in commercial steel may be considered to have but little influence upon its mechanical properties.

The addition of manganese to *pure* iron is without influence upon its ductility. The tensile strength of the alloys of iron and manganese are in excess of that of iron, the increase in maximum stress per 0.01 per cent. of manganese being about 90 pounds per square inch for alloys annealed at 30° C. above the transformation range.

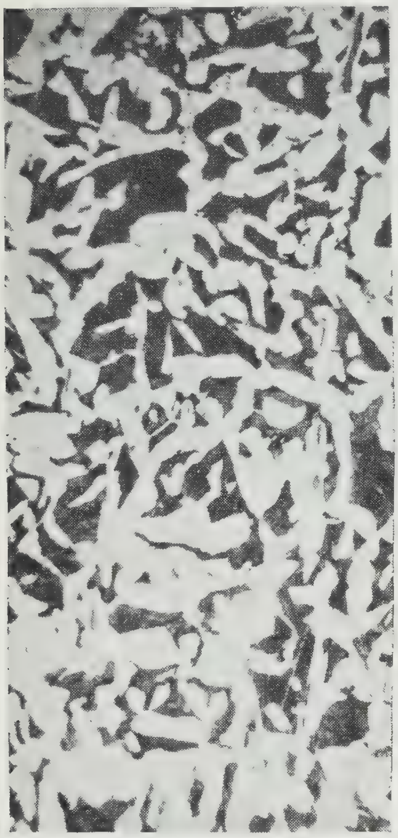


Fig 48

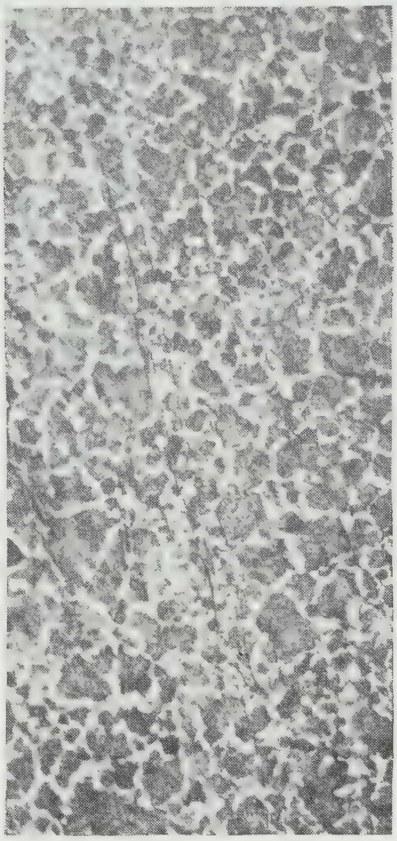


Fig. 49

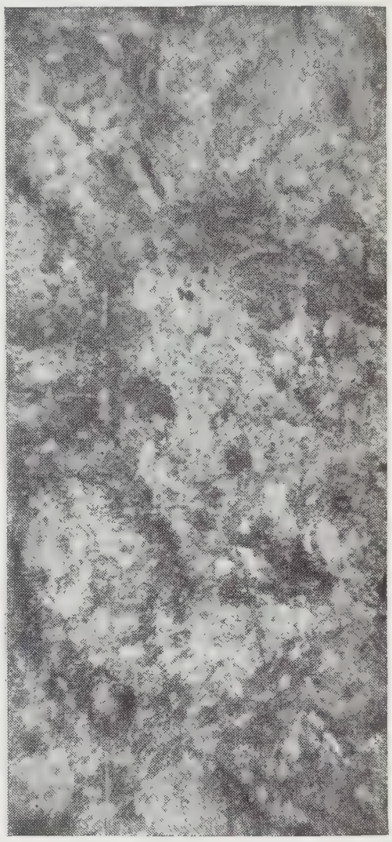


Fig. 50

Sections of steel showing increase of pearlite with increase in carbon content.
Pearlite: dark. Ferrite: white.

Fig. 48—0.33 per cent. C steel (forged).
Fig. 49—0.60 per cent. C steel (annealed 850°C).
Fig. 50—0.85 per cent. C steel (cast).
Magnification, 100 diameters.

In pure steels (free from all but the smallest trace of elements other than iron, carbon, and manganese), the rate of increase of proportional limit and tensile strength per 0.01 per cent. increase of managanese is as high as 230 pounds per square inch for steels containing upwards of about 0.75 per cent. of carbon. It will thus be seen that manganese may be expected to confer upon commercial steels properties well in excess of those that would be possessed by steels free from this element.

In commercial steels a proportion of manganese is associated with sulphur as manganese sulphide. Such manganese as is present in excess of that which combines with the sulphur of the steel (the percentage of sulphur as combined being about 1.7 times that of the percentage of sulphur present in the steel) is free to excerise an influence similar to that which is exercised by manganese upon the pure carbon steels.

Sulphur appears to reduce the yield point, maximum stress, and percentage elongation of steel and to increase its percentage reduction of area and resistance to shock. Sulphur occurs in steel in combination either with manganese or with iron.

Sulphur combines with iron to produce a sulphide, which with iron forms a eutectic, containing about 30 per cent. of sulphur and melting at a temperature of 985° C. This eutectic occurs in iron in the form of ovoids, oval laminae or membranes enveloping the crystal grains. It is the prime cause of hot shortness in steel.

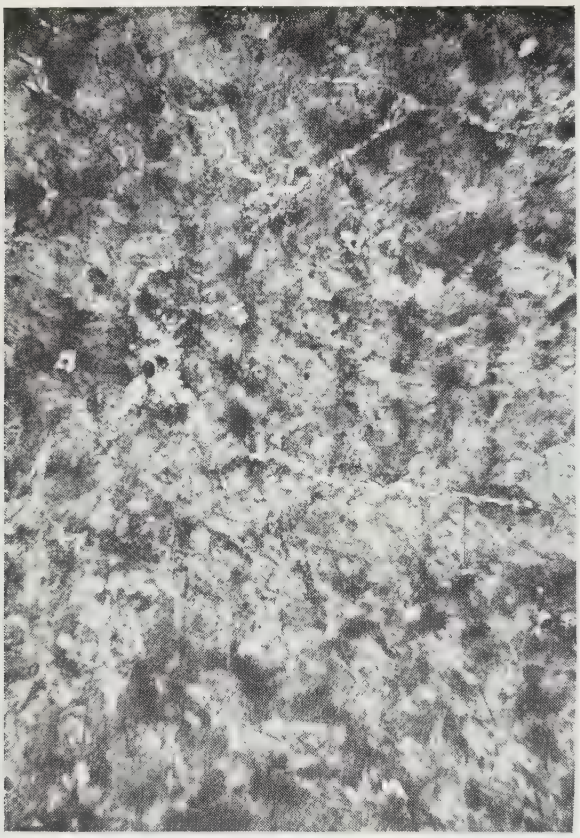


Fig. 51

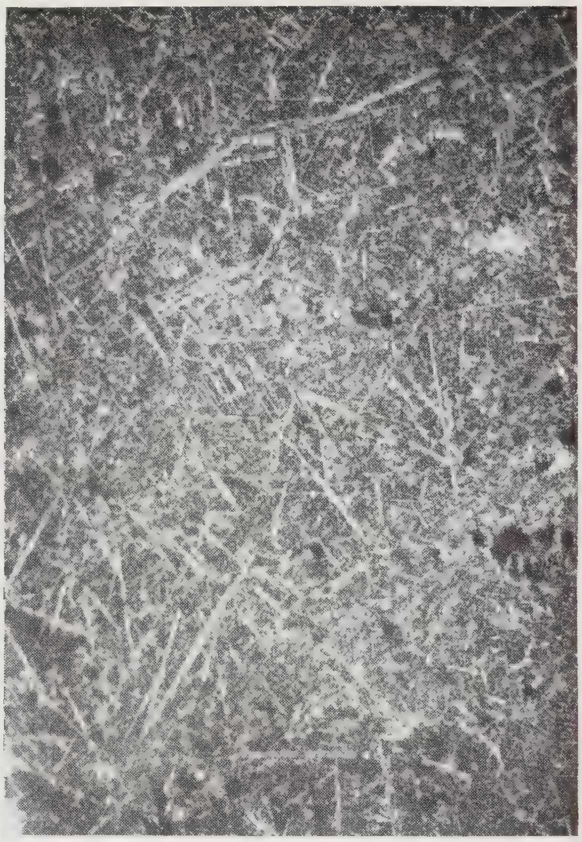


Fig. 52

Sections of steel showing increase of cementite with increase of carbon beyond 0.85 per cent.

Pearlite: dark. Cementite: white.

Fig. 51—1.2 per cent. carbon steel (cast).
Fig. 52—1.5 per cent. carbon steel (cast).
Magnification, 100 diameters.

The compound of sulphur and manganese, manganese sulphide, is, however, free from the objectionable characteristics of iron sulphide, and quite appreciable quantities of manganese sulphide may be present in steel without serious results ensuing; in fact, the free-cutting properties of certain steels are due to the deliberate introduction of sulphur, such steels sometimes containing as much as 0.15 per cent. of this element. Manganese sulphide is not without influence upon the mechanical properties of rolled steels. Ship plates, boiler plates, etc., containing manganese sulphide in quantity are weaker transversely than in the direction in which they are most extended by rolling.

The sulphur content of steels is advisably limited by specification. In structural steel, for example, a limit of 0.06 per cent. is usual, in tool steel 0.025 per cent., and so on.

Phosphorus has a marked effect upon the mechanical properties of carbon steel. Stead quotes the following figures for the influence of 0.10 per cent. of phosphorus in steel:—

Yield limit is raised 5,600 pounds per square inch.
Maximum stress is raised 5,400 pounds per square inch.
Percentage elongation is reduced 0.7 per cent. $\frac{\text{length}}{\text{area}} = 8$).
Percentage reduction is reduced 1.5 per cent.

The resistance of steel to shock is reduced as a result of the addition of phosphorus. In low-carbon steels not more than 0.10 per cent. is, as a general rule, allowable, though in machine stock relatively high proportions of this element are acceptable on account of the improvement in machineability induced by the phosphorus. In most cases a limit of 0.07 per cent. is specified. In high carbon steels the embrittling effect of phosphorus is quite appreciable, an increase of 0.01 per cent. in 100 per cent. carbon steel having a marked effect. An upper limit of 0.04 per cent., or even less, is considered advisable in tool steels.

ALLOY STEELS

Steels which contain silicon or manganese in excess of the amounts specified on page 133, and steels which contain elements other than silicon, manganese, sulphur, and phosphorus, may be termed alloy steels. Alloy steels may be defined as steels to which elements have been added for the express purpose of conferring upon them special characteristics.

The manufacture of silicon steels is preferably conducted in the acid open hearth furnace. These steels contain up to 4.52 per cent. of silicon, and rarely contain more than 0.50 per cent. of carbon.

The addition of silicon leads to a slight increase in the strength and hardness of steel. It is considered to increase the resistance of steel to shock, and on this account is a constituent of steels for automobile and railway springs. The silicon steels so used are generally referred to as silico-manganese steels, though the proportions of manganese present in these alloys do not exceed those present in commercial carbon steels. Typical specification requirements for silico-manganese steel bars for automobile and railway springs, are as follows:—

	Automobile springs	Railway springs
	per cent.	per cent.
Carbon	0.45 to 0.55	0.55 to 0.65
Manganese	0.60 to 0.80	0.50 to 0.70
Sulphur	0.045 (maximum)	0.045 (maximum)
Phosphorus	0.045 to 0.050	0.045 to 0.050
Silicon	1.80 to 2.10	1.50 to 1.80

These steels require special care in their heat treatment.

Silicon steels of low carbon content and containing from about 4 to 4.25 per cent. of silicon are extensively used in the manufacture of transformer sheets. The characteristics of these steels are a very low hysteresis combined with a high electrical resistivity.

A typical analysis of silicon steel for transformer sheets is as follows:—

	per cent.
Carbon	0.08
Manganese	0.11
Sulphur	0.06
Phosphorus	0.01
Silicon	4.18

Aluminum, phosphorus, nickel, and tungsten are similar in their effect upon the electrical properties of steel, but silicon is, on account of its cheapness, the element most extensively employed in this connection.

It is convenient to distinguish between manganese steels which on slow cooling are possessed of the structure of slowly cooled carbon steels (pearlitic manganese steels) and manganese steels which on slow cooling are characterized by a martensitic or austenitic structure. The pearlitic steels may be considered as containing up to 0.6 per cent. of carbon and from 1.0 up to 2.5 per cent. of manganese. The addition of manganese to steel results in a depression of the transformation range, and this fact should be taken into consideration whenever manganese steels of a pearlitic structure are the subject of heat treatment.

The investigations of Lang have demonstrated that manganese not only increases the hardness, the strength, and the hardening power of low-carbon steels, but that it does so without impairing the ductility of the steel. Lang has also shown that manganese in quantities up to 1.5 per cent. at least adds to rather than subtracts from the shock-resisting qualities of annealed mild steels. That pearlitic manganese steels of relatively high carbon content (0.60 per cent. carbon and 1.25 per cent. manganese) can also withstand shock when thermally treated in a scientific manner, is shown by the fact that such steels have been employed with success in the manufacture of shrapnel shells of as high a calibre as 13.5 inches.

Of martensitic steels, those containing from 7 to 8 per cent. of manganese have found employment in situations where the austenitic manganese steels are generally used. They are cheaper than the austenitic steels, which usually contain from 11 to 14 per cent. of manganese. They are, however, much less ductile than the austenitic manganese steels.

The austenitic steels are those generally referred to as "manganese steel" and the name "loman" has been suggested as a suitable title by which to distinguish the low manganese alloys referred to above from the 11 to 14 per cent. manganese steels.

The "manganese steels" are of the following approximate analysis:—

	per cent.
Carbon	1.00 to 1.3
Silicon	0.3 to 0.8
Sulphur	Trace
Phosphorus	0.05 to 0.08
Manganese	11.0 to 14.0

These steels are practically non-magnetic and are possessed of a remarkable resistance to abrasion. They may be forged and rolled, but are difficult to work. They are also hard to machine. The manganese steels are always used in a water-toughened state, water toughening consisting in heating the steel to about 1050° C., and quenching it in cold water.

Cast manganese steels are used in the lining of rock crushers working at low speeds; in the manufacture of car wheels that are to run at slow rates; in the manufacture of frogs, switches, and curved rails; of burglar-proof safes and vaults; and, on account of its non-magnetic properties, in the cover plates of heavy lifting magnetos.

Manganese steel has been successfully rolled into rails for railroads, and forged manganese steels have also found favour in other fields.

The manufacture of "manganese steel" is a somewhat specialized operation.

Chromium steels are manufactured by the same process as the carbon steels. They are rarely used in the untreated condition. Chromium raises the transformation ranges of steel.

The chromium steels may, for convenience, be divided into three classes:—

1. Steels containing about 0.5 per cent. of chromium, and from 0.50 to 1.50 per cent. of carbon.

2. Steels containing from 1.00 to 3.00 per cent. of chromium, and from 0.80 to 1.00 per cent. of carbon.

3. Steels containing from 12.00 to 17.00 per cent. of chromium, and up to 1.00 per cent. of carbon.

The chromium steels of the first group have somewhat higher mechanical properties than the corresponding carbon steels. The steels of lesser carbon content (below 1.00 per cent.) find employment in the manufacture of the shoes and dies of stamp mills for pulverizing gold and silver ores. They have also been used for chisels. The steels of higher carbon content have been extensively employed for drills, files, and saw blades.

Chromium steels of the second group are used on account of the extreme hardness that may be given to them by suitable heat treatment. For ball bearings and roller bearings, steels containing from 1.00 to 1.60 per cent. of chromium are used. For armour-piercing projectiles, a chromium content of about 2.25 per cent. has proved of service. For rolls (for cold rolling metals), 2.00 to 3.00 per cent. chromium steels have been used.

The chromium steels of the third group comprise the so-called "stainless steels." The resistance of these steels to corrosion is reduced by increasing the carbon content. Their chief use, at present, is in the manufacture of cutlery, the carbon content of such steel being about 0.30 per cent.

Certain of the higher carbon steels of this class have proved of service as valve steels in medium hot engines. They are superior in their machining properties to 18 per cent. tungsten steel and prove, therefore, of economical value in certain cases. A chromium steel containing about 17 per cent. of chromium and 1 per cent. of carbon has been used as a die steel.

"The range of strength available with 'stainless steels' is quite considerable, and, in fact, is equal, if not superior, to that obtainable with any other steel."

The nickel steels are manufactured by the same processes as the carbon steels. Nickel lowers the transformation range of steel.

What is generally referred to as "nickel steel" is the 3.5 per cent. alloy, which has proved of immense value in engineering work generally. Not only has it found employment in the manufacture of machine parts, engine parts, and automobile parts, but important quantities have been used with success in the construction of bridges of wide span, such, for example, as the Quebec bridge.

In the manufacture of automobile parts, 3.5 per cent. nickel steels containing 0.20, 0.30 and 0.40 per cent. of carbon are employed.

Low-carbon (0.10 per cent.) nickel steels containing from 2 to 6 per cent. of nickel are used in case-hardening practice.

Austenitic nickel steels (steels containing upwards of 25 per cent. of nickel and of low carbon content) are used in limited amounts. Tabulated below are the analyses of certain of these steels and the uses to which they are put:—

AUSTENITIC NICKEL STEELS AND THEIR USES

Per cent. nickel	
24 to 32	Resistance wire (electrical).
27	Bits, stirrups, spurs, etc. (owing to its resistance to corrosion).
30	Boiler tubes (owing to its resistance to corrosion).
36	Invar. (clock pendulums, etc.); coefficient of expansion, 0.0000008 per degree C.
46	Platinite (substitute for platinum); coefficient of expansion equal to that of glass.

Tungsten steels are made almost entirely by the crucible process. Three steels of this type are worthy of note:—

1. Three per cent. tungsten steel. This steel, which contains about 1 per cent. of carbon, is treated under almost the same conditions as the carbon steels. It may be considered as an improved tool steel; it is more desirable than straight carbon steel and is able to cut at a higher speed.

2. Six per cent. tungsten steel. This steel, which contains about 0.6 per cent. of carbon, is used in the manufacture of permanent magnets for electric motors, small dynamos, etc.

3. Eighteen per cent. tungsten steel. This steel, which contains about 0.65 per cent. of carbon, is of value on account of its retention of strength at high temperature. It is used in the manufacture of valves for use in the hottest automobiles and aircraft engines.

The molybdenum steels are very similar in character to the tungsten steels, one part of molybdenum conferring upon carbon steel properties approaching those conferred by two to three parts of tungsten. The molybdenum steels have not been widely used owing to difficulties encountered in their production and also to the scarcity of molybdenum. These steels have been used in situations similar to those in which the tungsten steels are employed.

The simple vanadium steels are somewhat limited in their application at the present time. Vanadium is, however, of frequent occurrence in more complex alloy steels. Vanadium is a powerful deoxidizer, and its use in this connection has been quite extensive. Vanadium increases the hardness of steel, and steels containing about 1 per cent. of the element have been used with success in the manufacture of tools. A steel containing about 0.20 per cent. vanadium has been employed for constructional purposes.

Steels to which more than one element is added with a view to modifying their physical and mechanical properties are frequently referred to as "complex" alloy steels. Examples of such steels are the nickel-chromium, the chromium-vanadium, the molybdenum-chromium, and the high-speed tool steels.

The nickel-chromium or chrome-nickel steels are perhaps the most important of the structural alloy steels. Steels containing up to 4.5 per cent. of nickel and 1.5 per cent. of chromium have found employment in the construction of automobile and aeroplane parts.

These constructional steels may be divided into three classes:—

Class	Carbon	Nickel	Chromium
	per cent.	per cent.	per cent.
1.	0.2 to 0.5	1.5	0.7
2.	0.1 to 1.5	3.0	0.6 to 0.9
3.	0.1 to 0.5	3.5	1.5

The low-carbon steels of each class are used in manufacture of parts finally to be case-hardened; the medium carbon steels are used for shafting and similar parts; and the higher carbon steels are employed in the manufacture of such parts as gears, crank shafts, and transmission lines.

These steels are almost invariably subjected to heat treatment before use. A wide range of properties is obtainable by varying the heat treatment of the steels in each class; a still wider range of characteristics is therefore attainable by the use of the whole series.

Chrome-nickel steels are used in the manufacture of armour plate and of armour-piercing projectiles.

A so-called natural chrome-nickel steel is made from ores mined at Mayari, Cuba. Mayari steel contains from 0.2 to 0.7 per cent. of chromium, and from 1.0 to 1.5 per cent. of nickel.

The chromium-vanadium steels are of recent development. These steels lie within the following limits of composition:—

	per cent.
Carbon	0.10 to 0.95
Manganese	0.50 to 0.80
Chromium	0.80 to 1.10
Vanadium	Over 0.15 (0.18 per cent. if desired)

These steels are similar in their physical properties to the chrome-nickel steels, but are relatively more ductile.

Chrome-vanadium steels find their largest use in the automobile industry. They are almost invariably used in the heat treated condition.

The uses to which the chrome-vanadium steels of varying carbon content are put, are tabulated below:—

CHROME-VANADIUM STEELS AND THEIR USES

Per cent. carbon	
0.15 to 0.25	Case hardened parts.
0.25 to 0.32	Automobile forgings.
0.32 to 0.40	Locomotive axles, crank-shafts, and crank-pins; automobile transmission lines and rear axle shafts.
0.45 to 0.65	Automobile and railway springs.
0.55 to 0.65	Rolled wheel and tire tools.

The molybdenum-chromium-nickel steels, containing small percentages of molybdenum (less than 1.00 per cent.) appear to have a promising future. They have been used with success in the manufacture of light engines, crank shafts, and armour plate. Chrome-molybdenum steels have also been used with success in the manufacture of armour-piercing projectiles. Analyses typical of steels of these types are as follows:—

	Steel for crank shafts per cent.	Steel for projectiles per cent.
Carbon	0.30	0.65
Manganese	0.69	0.80
Chromium	0.98	2.19
Molybdenum	0.54	0.84
Nickel	3.05	....

High-speed tool steels are all made by the crucible or electric furnace processes. They contain, apart from the usual elements, tungsten, chromium, and vanadium, sometimes cobalt; and rarely nickel and molybdenum. The carbon content of high-speed tool steel varies from 0.55 to 0.75 per cent. The tungsten content varies from about 13.0 to about 19.0 per cent. The chromium content from about 3.0 to about 5.0 per cent., and the vanadium content from about 0.5 to about 2.5 per cent.

Apart from the use of these complex steels in tools, they have found employment in the manufacture of exhaust valves for automobile engines and for dies in extension presses for brass.

6. PROGRESS IN ELECTRIC IRON SMELTING AND COST OF ELECTRIC SMELTING IN ONTARIO

By Alfred Stansfield

I. Progress in Electric Iron Smelting

The electric smelting of iron ores for the production of pig iron was started experimentally about the year 1900 in Europe, and in 1906 in Canada. Its greatest development has been in Sweden, where experiments were conducted from 1907 to 1909, and where it has been used commercially from 1910 to the present time. Electric smelting has been conducted commercially for a time in California, Japan, Italy, and elsewhere; but Sweden and Norway are the only countries in which the industry has become firmly established. The success of the industry in these countries cannot be explained entirely by the low cost of electric power and other supplies, but depends, also, on the existence in Europe of a market in which Swedish pig iron, smelted with charcoal from pure ores, commands a high price. In general it will not be possible to produce pig iron by smelting iron ore in electric furnaces unless the resulting iron, on account of its greater purity, can command a higher price than iron made by smelting the same ores with coke in a blast furnace, and it would be necessary, therefore, to find a market for the special qualities of iron that could be made by electric smelting.

In Sweden, electric smelting of iron ores is conducted almost entirely in the Elektrometall furnace, a somewhat elaborate appliance with a shaft like a blast furnace and with a system of circulation of the furnace gases. This furnace is more economical in fuel and electrical energy than other furnaces that have been tried, and it is the only one in regular commercial use for the production of pig iron from iron ore; but it is very costly and is not very well suited to the production of high-silicon or foundry iron. Iron ores have also been smelted electrically in open pit furnaces of the kind that is used regularly for the production of ferro-alloy. These furnaces are less economical of electrical power and of charcoal or coke, but they are far less costly; they are, also, I believe, more suitable than the Electrometall furnace for the production of high-silicon or foundry iron.

By the year 1921, fifteen Elektrometall furnaces had been built (fourteen in Sweden and one in Japan), having a combined electrical power of 54,000 kilowatts, or an average power of 3,600 kilowatts for each furnace. Furnaces planned and under construction were: four in Sweden, six in Italy, two in Brazil, and three in Norway, having a combined power of 50,000 kilowatts for the fifteen furnaces. The following table shows the production of pig iron in the Elektrometall and other electric furnaces in Sweden:—

Year	Elektrometall	Year	Elektrometall	Open pit	Total
	metric tons		metric tons	metric tons	metric tons
1908	132	1914	26,854	....	26,854
1909	302	1915	35,075	....	35,075
1910	890	1916	43,612	1,170	44,782
1911	5,786	1917	57,793	9,266	67,059
1912	17,561	1918	59,176	16,508	75,684
1913	31,966	1919	57,883	6,587	64,470

The records show that 10 Elektrometall furnaces, with a combined power of 36,000 kilowatts, had been constructed by the year 1917, but the output during the years 1917, 1918, and 1919 corresponds to the continuous operation of only 5 furnaces with a combined power of 18,000 kilowatts.

Open pit furnaces were used in Sweden during the war for the production of foundry iron, but this was mainly by the fusion of steel scrap with carbon, and only to a small extent by the smelting of iron ore.

In California, the furnace that was found most suitable was a rectangular furnace like a ferro-alloy furnace, but having a roof and charging chutes for the ore. The product required in California was a foundry iron, and it was no doubt for this reason that this simpler type of furnace was preferred. The smelting of iron ores in the West was given up about the year 1914, apparently for financial rather than technical reasons. During the war a quantity of foundry iron was made there in an open pit furnace such as is used for making ferro-alloys.

Pig iron made in electric furnaces in British Columbia and other parts of Canada during the war, was mostly "synthetic pig iron," that is, iron produced by melting steel scrap with the necessary carbon and other additions.

II. Cost of Electric Smelting of Iron Ores in Ontario

INTRODUCTION

This report is intended to show the probable cost of making pig iron by smelting Ontario ores in electric furnaces.

I was requested by the committee to base the report on the smelting of three different ores:

1. A hematite ore containing 50 per cent. of iron and with the ordinary siliceous gangue.
2. A magnetite ore containing 50 per cent. of iron and with the ordinary siliceous gangue.
3. A magnetite concentrate, such as that from Moose Mountain, containing 64 per cent. of iron and sintered or briquetted.

The committee also furnished me with analyses of Atikokan, Moose Mountain, Magpie, and Helen ores, and with coke and limestone analyses, all of which are given on page 151.

I was not furnished with the cost of the ore, fuel, and other supplies, but was asked to leave my estimate in such form that these costs could be inserted to suit any particular locality. In regard to electric power, however, I was asked to assume that the cost would be $18 per e.h.p. year.

The estimate was to apply to the cost of making pig iron in a plant of 350 tons per day, and the cost of such a plant was also to be given. The kind of pig iron to be made was not specified, but I have estimated on the production of a low-silicon iron, suitable for steel-making, and also on a high-silicon or foundry iron. I was asked to give my opinion as to the quality of pig iron, so made, as compared with the various grades of pig iron that would be made in the blast furnace from similar ores.

No location was assigned to the proposed plant, but I have assumed that it would be at some point in Ontario where ore and other supplies could be obtained by water transportation and where electric power would be available at a moderate cost.

In view of the information available with regard to the smelting of iron ores in the Elektrometall and the open pit furnaces, I am of the opinion that the former would be found to be the more economical for the production of a low-silicon pig iron, but that the latter would be preferable for the production of foundry iron. I have made estimates of the cost of smelting iron ores in furnaces of both kinds.

PLANT FOR ELECTRIC SMELTING

The proposed plant is to have an output of about 350 tons of iron per day. I shall assume that the product will be partly low-silicon iron, suitable for steel-making or the production of malleable castings, and partly high-silicon iron suitable for the grey iron foundry.

In order to determine the size of the plant, I shall make the general assumption, in view of the character of the ores and of the pig iron, that each electric horse power supplied to the plant will produce 0.25 long tons of iron per annum. This figure corresponds approximately, having regard to the probable load factor, with the consumption of 2,400 kilowatt-hours per long ton. On this basis, an average daily output of 350 long tons would need 51,000 e.h.p., or 38,000 kilowatts. These figures will include the lighting and mechanical power needed in the smelting plant.

I have obtained from the A/B Elektrometall of Sweden, through the kindness of their American representative,[1] an estimate of the cost of a plant of the Swedish type having the desired output. Their calculation is based on the use of an ore mixture containing equal parts of low-silicon iron and foundry iron. It also provides for the use of either coke or charcoal, presumably in equal proportions.

They recommend the installation of seven Elektrometall furnaces, each of 6,000 kw., one of which would be held in reserve. They would thus have a total working load of 36,000 kw., a figure which agrees with my previous estimate, made independently. These furnaces are each provided with eight electrodes of 28-inch diameter and are of the usual Swedish type with a high shaft and circulation of the gases. The A/B Elektrometall gives the following estimate of the cost of such a plant:—

ESTIMATED COST OF ELEKTROMETALL PLANT

Electrical transformers, motors, controls, and low tension conductors..........	$450,000
Seven furnaces, complete with fan, gas pipes, connections, and refractories......	700,000
Drawings, plans and specifications, and operating license, and all miscellaneous expenditure..........	285,000
Excavations, levelling, railway tracks, storehouse for ore, coke, charcoal, furnace foundations..........	140,000
Buildings: Furnace building ($300,000); crusher plant laboratory, workshop for repairs, store house, etc. ($30,000)..........	330,000
Travelling cranes and transporting devices..........	100,000
Moulds, ladles, tools, and instruments..........	60 000
Ore crushers..........	10,000
Water pipes and waste pipes..........	25,000
Total..........	$2,100,000

[1]Frank Hodson, President of the Electric Furnace Construction Co., 908 Chestnut Street. Philadelphia.

I have obtained from the Volta Manufacturing Company, of Welland, through the kindness of Mr. Robert Turnbull, an estimate of the cost of a plant of the same output, but provided with furnaces of the open pit type.

The plant would contain 10 furnaces of 4,000 kv-a. each, or 40,000 kv-a. in all. The cost is very much less than for the Elektrometall plant.

ESTIMATED COST OF PLANT WITH OPEN PIT FURNACES

Main building, 456 ft. long, 55 ft. span, with lean-to for transformer room, 456 ft. by 17 ft., approximately 35,000 sq. ft.	$60,000
Machine shop building and machinery	15,000
10 three-phase, 4,000 kv-a. transformers	150,000
Control equipment, meters, etc.	20,000
1 main oil circuit-breaker	3,000
High tension wiring and supports	2,500
Electrode equipment complete, including regulators	60,000
Pump and water supply	3,000
Crusher and conveyor	4,000
Pig machine and equipment	20,000
1 ten-ton derrick	15,000
2 ten-ton cranes	20,000
1 locomotive	17,500
Bins and storage equipment	25,000
10 furnaces, complete with linings	35,500
Total	$450,000

Mr. Turnbull considers that with the addition of $50,000 for contingencies, bringing the total up to $500,000, the estimate can be safely accepted.

Comparing the two estimates, it is found:—

1. The Elektrometall estimate provides seven furnaces, of which only six will be in use at once, while the Volta estimate provides merely the number in use. A spare furnace is essential to the Swedish plant as a considerable time would be needed for rebuilding or serious repairs to a furnace of that type.

2. The electrical transformers, motors, controls, and low tension conductors in the Swedish estimate cost $450,000, while the corresponding items in the Volta plant amount to $85,500. The electrical transformers are necessarily more costly in the Swedish design, as they are single-phase instead of three-phase, and as they must provide a variable voltage.

The cost of transformers forms an important part of the whole cost of an electric smeltinn plant, and as it is an item for which a definite figure could be obtained, I asked the Canadiag General Electric Company for an approximate estimate for this part of the design.

The plant using open pit furnaces needs 10 three-phase, 4,000 kv-a. transformers, which are estimated by the Volta Company to cost $150,000. The Canadian General Electric Company quote a price, f.o.b. Davenport works and subject to Government sales tax, of $8,750 per transformer, or $87,500 for the ten transformers.

The Elektrometall transformers are more costly for the following reasons: (a) The transformers are single-phase instead of three-phase. (b) They have taps on the primary windings so as to reduce the voltage by steps from 100 to 60. This makes the construction more complicated and practically doubles the size of the windings, as the full power must be available at each voltage. (c) For the 8-electrode furnaces, which use a double two-phase current, the Electric Company advise that it would not be convenient to employ the usual Scott connection, on account of the primary taps, and recommend the use of two extra transformers per furnace for changing from three-phase to two-phase current.

The Canadian General Electric Company's estimate for one 7,000 kv-a. furnace would be as follows:—

4 1,750 kv-a. single-phase transformers at $6,200	$24,800
2 600 kv-a. " " " 2,900	5,800
	$30,600
Transformers for seven furnaces	$214,200

The transformers for the open pit furnaces have a combined capacity of 40,000 kv-a., while those for the Elektrometall furnaces have a capacity of 49,000 kv-a. If we increase the former cost in the ratio of 49 to 40, we obtain a figure of $107,000.

It will be seen that the transformers for the Elektrometall plant would cost twice as much as those of the open pit plant for equal capacity.

The Elektrometall estimate for transformers, motors, controls, and low tension conductors was $450,000. The cost of the transformers was found to be $214,200, and the other items may raise this figure to $250,000 or $270,000.

The information obtained from the Canadian General Electric Company explains in part the great difference between the estimates for electrical apparatus in the two plants, but it does not fully explain the very high cost of the Swedish plant.

3. The Swedish furnaces cost $100,000 each, while the Volta furnaces cost $3,500 each, for an equal output. The Swedish furnace is undoubtedly far more expensive than the open pit furnace, but a ratio of ten times would seem to be a sufficient difference.

4. The buildings in the Swedish plant cost $330,000, while those in the Volta plant cost $75,000. On account of the greater height of the furnaces and of the gas circulation apparatus, the Swedish furnace room will have perhaps three times the volume of the Volta furnace room; it is probable also that a more substantial building is intended.

5. In the Swedish estimate there is an item of $285,000 for drawings, plans, and specifications, and operating license, which does not appear at all in the Volta estimate.

In conclusion, without going any further into details, it appears probable that the Elektrometall plant could be built somewhat more economically under Canadian conditions, and that the Volta estimate may need to be increased to represent an equally permanent type of plant. In my calculations, however, I have assumed that the Swedish plant would cost $2,000,000 and the Volta plant $500,000.

SUPPLIES FOR ELECTRIC SMELTING

I have calculated the amount of ore, charcoal or coke, and limestone that would be needed for the production of one long ton of pig iron from each of the three ores. The calculations show the quantities needed for the production of a foundry iron and of a basic iron, using charcoal and using coke, and smelting in the open pit and in the Elektrometall furnace. They also show, in each case, the amount of slag produced. There are twenty-four separate cases to be calculated, and I wish to thank Mr. W. R. McClelland, a graduate student in the Metallurgical Department at McGill, who did most of the numerical work under my direction.

The results of such calculations depend very greatly on the precise assumptions that are made as to the analyses of the ore, fuel, slag, and furnaces gases. I am, therefore, giving the data that were assumed in each case. It will be easy, in any actual case, to modify the results in view of the change in the data.

DATA ASSUMED FOR THE CALCULATION OF CHARGES

<table>
<tr><th></th><th>Fe</th><th>SiO_2</th><th>Al_2O_3</th><th>CaO</th><th>MgO</th><th>Fe_2O_3</th><th>CO_2</th><th>CO</th><th>C</th><th>S</th><th>Ash</th><th>Si</th></tr>
<tr><td></td><td>%</td><td>%</td><td>%</td><td>%</td><td>%</td><td>%</td><td>%</td><td>%</td><td>%</td><td>%</td><td>%</td><td>%</td></tr>
<tr><td>Hematite</td><td>50</td><td>10</td><td>2</td><td colspan="2">6</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Magnetite</td><td>50</td><td>11</td><td>22</td><td colspan="2">7</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Sintered concentrate</td><td>64</td><td>4.5</td><td>0.5</td><td colspan="2">1</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Limestone</td><td></td><td>2</td><td>0.5</td><td colspan="2">53</td><td>0.5</td><td>44</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Coke</td><td></td><td>7</td><td>2</td><td>1</td><td></td><td></td><td></td><td></td><td>[1]88.5</td><td>0.75</td><td></td><td></td></tr>
<tr><td>Charcoal</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>[1]75</td><td></td><td>[2]2</td><td></td></tr>
<tr><td>Foundry iron</td><td>94</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>3.5</td><td></td><td></td><td>2.5</td></tr>
<tr><td>Basic iron</td><td>95</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>3.5</td><td></td><td></td><td>0.8</td></tr>
<tr><td>Furnace gases:</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Elektrometall furnace:</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Hematite</td><td></td><td></td><td></td><td></td><td></td><td></td><td>30</td><td>60</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Magnetite</td><td></td><td></td><td></td><td></td><td></td><td></td><td>25</td><td>65</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Open pit furnace:</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Hematite</td><td></td><td></td><td></td><td></td><td></td><td></td><td>10</td><td>80</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Magnetite</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>90</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Slags:</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Coke:</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Basic</td><td></td><td>32</td><td>10</td><td colspan="2">55</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Foundry</td><td></td><td>36</td><td>11</td><td colspan="2">50</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Charcoal:</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Basic</td><td></td><td>38</td><td>10</td><td colspan="2">48</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Foundry</td><td></td><td>40</td><td>11</td><td colspan="2">45</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

[1]Fixed.
[2]Equal to 0.6 per cent. available base.

The amount of lime and magnesia in the ores is rather high for a "siliceous gangue," but it was adopted in view of the analysis of the Atikokan ore, while the Magpie and Helen ores are far higher in lime and magnesia. An ore containing only 50 per cent. of iron and 15 or 16 per cent.

of silica would need a very large amount of flux and would be very costly to smelt. The ores are supposed to contain 2 or 3 per cent. of moisture. It is assumed that the concentrate has been sintered and that the iron is in the form of Fe_3O_4. The limestone represents a mean between the Dundas and Hanover stones.

The relation between the CO and CO_2 in the furnace gases makes it possible to calculate the amount of fuel needed per ton of pig iron. This calculation should be accurate in the case of the Elektrometall furnace, which is closed; but in the open pit furnace, fuel may be burned by exposure to air at the top of the furnace, and it is impossible to estimate this. The use of unburnt limestone increases the consumption of fuel, and this has been included in the calculations.

The alumina in the slag cannot be controlled with a given ore, and is included in the table merely to give a general idea of the analysis; the essential feature being the ratio of lime and magnesia to silica.

In the calculations it is assumed that 98 per cent. of the iron in the ore enters the pig iron.

The following tables give the results of these calculations together with the consumption of electrical power and electrodes and the average daily product in each case. Charges for repairs, labour and staff, interest and depreciation, are entered in the table and are explained further on.

CALCULATIONS FOR ELEKTROMETALL FURNACE PER 2,240 POUNDS OF PIG IRON

	Charcoal		Coke	
	Basic iron	Foundry iron	Basic iron	Foundry iron
CONCENTRATE:				
Ore.......long tons	1.52	1.50	1.52	1.50
Fuel....... " "	0.36	0.36	0.31	0.31
Flux....... " "	0.10	0.01	0.22	0.07
Slag....... " "	0.17	0.11	0.24	0.16
Electrodes.......lbs.	12	17	13	19
Kw-hrs.......	1,900	2,100	2,000	2,200
H.p year.......	0.32	0.36	0.34	0.37
Output.......long tons	425	385	400	365
Repairs.......	$0.35	$0.45	$0.40	$0.50
Labour and staff.......	1.70	1.85	1.80	1.95
Interest and depreciation.......	2.05	2.30	2.20	2.40
HEMATITE:				
Ore.......long tons	1.95	1.92	1.94	1.92
Fuel....... " "	0.37	0.38	0.35	0.34
Flux....... " "	0.22	0.16	0.45	0.22
Slag....... " "	0.48	0.44	0.60	0.50
Electrodes.......lbs.	15	20	16	22
Kw-hrs.......	2,300	2,500	2,400	2,600
H.p. year.......	0.39	0.43	0.41	0.44
Output.......long tons	350	320	335	310
Repairs.......	$0.45	$0.55	$0.50	$0.60
Labour and staff.......	2.05	2.25	2.15	2.30
Interest and depreciation.......	2.50	2.75	2.60	2.85
MAGNETITE:				
Ore.......long tons	1.94	1.92	1.94	1.92
Fuel....... " "	0.36	0.37	0.34	0.33
Flux....... " "	0.22	0.08	0.50	0.23
Slag....... " "	0.52	0.44	0.70	0.54
Electrodes.......lbs.	15	20	16	22
Kw-hrs.......	2,300	2,500	2,400	2,600
H.p. year.......	0.39	0.43	0.41	0.44
Output.......long tons	350	320	335	310
Repairs.......	$0.45	$0.55	$0.50	$0.60
Labour and staff.......	2.05	2.25	2.15	2.30
Interest and depreciation.......	2.51	2.75	2.61	2.85

1 h.p. year at 90 per cent. load factor, equals 5,880 kw-hrs.
Output calculated on a 50,000 h.p. supply.
Labour calculated on $715 per daily output.
Interest and depreciation on $2,000,000, or $877 per day.

CALCULATIONS FOR OPEN PIT FURNACE PER 2,240 POUNDS OF PIG IRON

	Charcoal		Coke	
	Basic iron	Foundry iron	Basic iron	Foundry iron
CONCENTRATE:				
Ore........long tons	1.52	1.50	1.52	1.50
Fuel........ " "	0.43	0.43	0.38	0.37
Flux........ " "	0.13	0.03	0.24	0.10
Slag........ " "	0.17	0.12	0.26	0.18
Electrodes........lbs.	22	27	23	29
Kw-hrs........	2,100	2,300	2,200	2,400
H.p. year........	0.36	0.39	0.37	0.41
Output........long tons	385	350	365	335
Repairs........	$0.35	$0.45	$0.40	$0.50
Labour and staff........	2.10	2.30	2.20	2.40
Interest and depreciation........	0.60	0.65	0.60	0.65
HEMATITE:				
Ore........long tons	1.94	1.92	1.94	1.92
Fuel........ " "	0.46	0.46	0.41	0.40
Flux........ " "	0.22	0.09	0.46	0.23
Slag........ " "	0.48	0.42	0.64	0.53
Electrodes........lbs.	25	30	26	32
Kw-hrs........	2,500	2,700	2,600	2,800
H.p. year........	0.43	0.46	0.44	0.48
Output........long tons	320	300	310	290
Repairs........	$0.45	$0.55	$0.50	$0.60
Labour and staff........	2.50	2.65	2.60	2.75
Interest and depreciation........	0.70	0.75	0.70	0.75
MAGNETITE:				
Ore........long tons	1.94	1.92	1.94	1.92
Fuel........ " "	0.44	0.44	0.41	0.40
Flux........ " "	0.23	0.09	0.49	0.25
Slag........ " "	0.52	0.44	0.70	0.56
Electrodes........lbs.	25	30	26	32
Kw-hrs........	2,500	2,700	2,600	2,800
H.p. year........	0.43	0.46	0.44	0.48
Output........long tons	320	300	310	290
Repairs........	$0.45	$0.55	$0.50	$0.60
Labour and staff........	2.50	2.65	2.60	2.75
Interest and depreciation........	0.70	0.75	0.70	0.75

Output calculated on a 50,000 h.p. supply.
Labour calculated on $800 per daily output.
Interest and depreciation on $500,000, or $219 per day.

POWER CONSUMPTION

A large amount of detailed information has been published with regard to the operation of the Elektrometall furnace at Trollhättan, and by a study of this it is possible to arrive at fairly dependable figures.

The Swedish company gives data showing the differences between the production of foundry iron and basic iron, and between the use of magnetite ores of different percentages of iron. I do not find any important difference between a magnetite and hematite of the same percentage of iron. The A/B Elektrometall gave me the following figures for smelting a mixture of the three ores:—

	Charcoal		Coke	
	Basic iron	Foundry iron	Basic iron	Foundry iron
Kilowatt hours........	2,300	2,500	2,400	2,600

These figures agree with those I have given for magnetite ores and are 6 per cent. higher than the average of my figures. I regard this difference as a factor of safety or as an allowance for irregular use of the power, which I have provided for at a later stage.

Very little information is available with regard to the consumption of power in open pit furnaces. The amount will be higher for the following reasons:—

1. In view of the lower percentage of CO_2 in the waste gases, the carbon of the fuel will furnish less heat to the furnace, and, therefore, more electrical power will be needed. This difference, even in spite of the fact that more carbon is used in the open pit furnace, means from 200 to 300 kilowatt hours more in the open pit than the Elektrometall furnace.

2. The gases escape from the open pit furnace at a far higher temperature than from the Swedish furnace, and so take more heat from the furnace. The difference between the two may be from 100 to 300 kilowatt hours per ton of iron.

On the other hand, the Swedish furnace is larger than the open pit, and there is more surface from which radiation can take place.

Balancing the various points, it seems safe to assume that there is a difference of at least 200 kilowatt hours per ton between the two furnaces, or an average increase of 8 per cent. above the Swedish furnace, and this figure has been used in preparing the calculations for open pit furnaces. In this connection the American representative of the Swedish company assures me that the Swedish furnace is 25 to 30 per cent. better than the open pit, while Mr. Turnbull considers that owing to the more direct control of the smelting that is possible in the open pit, this furnace will use as little power as the Swedish furnace. The figures I have given for the open pit furnace are in agreement with data given me by Mr. Turnbull, and are lower than I have from other sources.

Cost of Power

The committee gave me the figure of $18 per electrical horse-power year. This would represent a flat rate for each horse-power contracted for, and in changing from kilowatt hours into horse-power years, constancy of the load must be considered. In my Swedish report, 1914, I calculated that a single furnace of the Elektrometall type only used 82 or 83 per cent. of the power supplied to the plant, the difference representing mechanical power and light in the plant, imperfect load factor while operating, and delays for repairs and holidays. In a large plant with at least four furnaces, it is claimed that as much as 92 per cent. of the power can be utilized, but for the purpose of this report I have made my calculation on a basis of 90 per cent., and have used the same factor for both types of furnace. This means that I have assumed a year of 8,760 hours multiplied by 0.9, or 7,884 hours in converting from kilowatt hours to horse-power years.

The "output" in the tables means the average daily output during the year, on the basis of a total supply to the plant of 50,000 horse-power. The actual daily output when there were no delays might be 5 per cent. higher.

Electrodes

The consumption of electrodes appear to be decidedly higher in the open pit than in the Swedish furnace. I have assigned figures to the various cases in the Elektrometall furnace and have made a constant addition of ten pounds to these for the open pit operations. These figures refer to good quality carbon electrodes which cost about 5 cents per pound.

LABOUR AND STAFF

The Volta plant furnished me, through Mr. Turnbull, with the following estimate of the labour and staff required for their proposed plant of ten 4,000 kv-a. furnaces:—

3 men per furnace, 3 shifts per day	90
5 charge men, 3 shifts per day	15
1 foreman	1
15 yardman, 15 plus 7	22
1 foreman	1
6 machinists, 6 plus 2	8
3 helpers, 3 plus 1	4
1 foreman	1
1 superintendent	1
2 chemists	2
2 hippers	2
1 storekeeper, 1 plus 1	2
4 electricians, 4 plus 1	5
6 office help	6
1 manager	1
Total	161

For the Elektrometall plant of six 6,000 kilowatt furnaces, I have assumed 4 men per furnace, or a total of 72 furnace men, instead of 90, and the remainder of the staff as above, making a total of 143. At an assumed rate of pay the daily charge for the open pit plant came to $800, while the charge for the Elektrometall plant came to $715, the difference depending on the larger units in the latter plant. The cost per ton in each case has been obtained by dividing the total daily cost by the daily output.

The A/B Elektrometall give the following hours of labour as required for one ton of iron in the following cases:—

	hours
Basic charcoal iron	2.0
Foundry charcoal iron	2.2
Basic coke iron	2.1
Foundry coke iron	2.3

Assuming a rate of 60 cents per hour, we find a charge of $1.20 to $1.38 per ton, which is very much less than the above mentioned charges. It probably does not include the cost of the officials and the remainder of the staff.

The Swedish firm give a charge of 30 to 40 cents for "overhead." I have not included this in the tables as it is largely included in the charge I have assigned to "labour and staff." Some charge should, however, be made for overhead.

REPAIRS

A/B Elektrometall gave the following charges for repairs per ton of iron:—

	cents
Basic charcoal iron	40
Foundry charcoal iron	50
Basic coke iron	45
Foundry coke iron	55

I have modified these slightly in view of the different grades of ore and have assumed the same figures for the open pit furnaces.

INTEREST AND DEPRECIATION

In view of the very high cost of the Elektrometall plant, it is essential to include a figure for interest and depreciation in making a comparison between the costs in the two plants. I have taken interest at 6 per cent., and depreciation at 10 per cent. This amounts to $877 per day on the $2,000,000 Elektrometall plant, and $219 per day on the $500,000 open pit plant. In each case in the tables I have divided these figures by the daily output.

COST PER TON OF PIG IRON

The main items of cost can be made up from the table. The following are given as examples, assuming that the 50 per cent. ores cost $4.50 per gross ton, and the sintered concentrate $6.50 per gross ton; also, that coke costs $8.00 per net ton, and charcoal $15.00 per net ton; limestone $2.00 per net ton, and electric power $18.00 per continuous horse-power year.

EXAMPLE 1.—BASIC IRON, SMELTING HEMATITE WITH COKE IN SWEDISH FURNACE

Ore, 1.94 tons at $4.50 per ton	$8.75
Coke, 0.35 tons at $8 per net ton	3.15
Limestone, 0.45 tons at $2 per net ton	1.00
Electrodes, 16 lbs. at 5 cents per lb.	.80
Power, 0.41 h.p. year at $18	7.40
Repairs	.50
Labour and staff	2.15
Interest and depreciation	2.60
Total	$26.35

EXAMPLE 2.—BASIC IRON, SMELTING HEMATITE WITH COKE IN OPEN PIT FURNACE

Ore, 1.94 tons at $4.50 per ton	$8.75
Coke, 0.41 tons at $8.00 per net ton	3.65
Limestone, 0.46 tons at $2 per net ton	1.00
Electrodes, 26 lbs. at 5 cents per pound	1.30
Power, 0.44 h.p. year at $18	7.95
Repairs	.50
Labour and staff	2.60
Interest and depreciation	.70
Total	$26.45

The average price quoted for basic blast furnace iron during 1922 was about $24.

EXAMPLE 3.—CHARCOAL FOUNDRY IRON FROM CONCENTRATE IN SWEDISH FURNACE

Ore, 1.50 tons at $6.50 per ton	$9.75
Charcoal, 0.36 tons at $15 per net ton	6.05
Limestone, 0.01 tons at $2.00 per net ton	.02
Electrodes, 17 lbs. at 5 cents per pound	.85
Power, 0.36 h.p. year at $18	6.50
Repairs	.45
Labour and staff	1.85
Interest and depreciation	2.30
Total	$27.77

EXAMPLE 4.—CHARCOAL FOUNDRY IRON FROM CONCENTRATE IN OPEN PIT FURNACE

Ore, 1.50 tons at $6.50 per ton	$9.75
Charcoal, 0.43 tons at $15 per net ton	7.25
Limestone, 0.03 tons at $2 per net ton	.07
Electrodes, 27 lbs. at 5 cents per pound	1.35
Power, 0.39 h.p. year at $18	7.05
Repairs	.45
Labour and staff	2.10
Interest and depreciation	.60
Total	$28.62

The average price for Lake Superior charcoal iron during 1922 was $31.66.

These examples show that there is very little difference in cost of operation between the Elektrometall and the open pit furnace, when the interest and depreciation are taken into account. They also show that the operation of an electric smelting plant will be more likely to be profitable if a high-grade iron can be made and sold than in the production of an ordinary grade of iron.

QUALITY OF THE PIG IRON

Pig iron made in the electric furnace is, in general, superior to iron made from the same ores in the blast furnace.

1. When smelting with coke in the electric furnace, the amount of coke is about 35 per cent. of the amount used in the blast furnace, and thus, when ores that are low in sulphur are being smelted, the amount of sulphur in the charge for the electric furnace will be less than half of that in the charge for the blast furnace. In consequence the resulting pig iron should be much lower in sulphur.

2. It is possible in the electric furnace to effect a more perfect removal of sulphur than in the blast furnace, as was shown in the experiments at Sault Ste. Marie, and it may thus be possible to produce pig iron of fair quality from an ore that is high in sulphur. In view, however, of the high cost of electric smelting, I would not recommend its use for sulphurous ores, but would assume that an ore, such as the Atikokan, which has 2 per cent. of sulphur, would be roasted to remove the sulphur before being smelted.

3. When ores are being smelted with charcoal, very little sulphur is introduced with the fuel, but the charcoal carries an appreciable amount of phosphorus. In electric smelting, as much less charcoal is used, it is possible to obtain a lower percentage of phosphorus in the iron than when smelting in the blast furnace. In coke smelting, also, the electric furnace product will be lower in phosphorus.

4. The electric smelting furnace, particularly the Elektrometall furnace, is very suitable for the production of exceedingly low silicon pig iron by smelting with charcoal, as a low silicon iron can be obtained without danger of having a high sulphur content.

5. High silicon pig iron can be obtained with ease in the electric furnace, and for this purpose the open pit furnace seems to be the most suitable.

6. Electric furnace iron is apt to be somewhat low in carbon when compared with blast furnace iron, but apparently the carbon is high enough for steel-making or the foundry.

7. Electric furnace iron is usually freer from oxides and is stronger than similar iron made in the blast furnace.

COMPARISON OF THE OPEN PIT AND THE ELEKTROMETALL FURNACE

The operating cost of producing pig iron must be lower in the Elektrometall than in the open pit furnace, but when allowance is made for the higher cost of the former plant, it appears that there is not much difference between the two. The Elektrometall is, however, the only furnace that has been operated commercially for any considerable time, and as other types of furnace have been tried in Sweden, it may be concluded that for the production of basic iron, the Elektrometall furnace is better commercially than the open pit.

In calculating the cost of operating the open pit furnace, I may have underestimated the consumption of fuel, as some may burn on top of the charge; on the other hand, a cheaper grade of fuel can be used in the open pit furnace. I have assumed that these considerations will balance.

It should be remembered that the Elektrometall furnace is a finished metallurgical appliance which works regularly and quietly, while the operation of the open pit furnace is attended with the production in the smelting house of a large amount of flame, furnace gases, and dust, which make the operation far more unpleasant. In view of this, the charge for labour should probably be relatively higher for the open pit than the Elektrometall furnace.

The A/B Elektrometall state that foundry iron can be made and that coke can be used in their type of furnace, but I would prefer to try the open pit furnace if foundry iron is required, and perhaps also when coke is to be used for fuel.

CONCLUSION

I have given figures with regard to cost of plant and operating expenses from which the cost of electric smelting of iron ores can be calculated.

The cost of electric smelting is necessarily somewhat high, but in view of the rapid increase in the cost of coke for blast furnace operation, the electric smelting of iron ores may become commercially possible in suitable localities.

In view of the high cost of the process, it should be used for fairly high-grade ores, to keep the cost as low as possible, and for ores that are low in sulphur and phosphorus, so that a high-grade iron will result. It seems desirable to use charcoal instead of coke, if this can be obtained at a reasonable cost.

If conditions are found which make electric smelting feasible, I would recommend that a plant be designed to contain two separate electric furnace installations, one of open pit furnaces intended for the production of foundry iron, and the other of Elektrometall furnaces for the production of basic iron. I would suggest the erection at first of one Elektrometall furnace and perhaps two open pit furnaces. These would be operated under careful control for six months or a year so that a full comparison could be obtained of their operation. After that the remainder of the plant could be erected in view of the experience gained.

ANALYSES OF ORE, STONE, AND COKE

The following analyses and other information were collected in view of this report.

IRON ORES

	Helen ore raw	Magpie ore roasted	Atikokan ore as shipped	Moose Mountain ore	
				Natural	Dried
	per cent.	per cent.	per cent.	per cent.	per cent.
Iron	35.61	50.00	59.85	59.48	63.03
Silica	7.28	8.91	8.68	6.79	7.20
Alumina	12.00	1.39	1.51	0.32	0.34
Lime		7.72	3.00	0.28	0.30
Magnesia		7.92	2.54	0.24	0.26
Manganese	2.09	2.48	0.11	0.07	0.07
Sulphur	2.00	0.20	2.01	0.03	0.032
Phosphorus	0.016	0.018	0.11	0.015	0.015
Copper	....	....	0.12	....	....
Nickel	....	....	0.11	....	....
Titanium	....	....	none	....	....
Loss on ignition	31.56	none	....	....	....
Moisture	....	1.00	....	5.63	....

LIMESTONE

	Dundas stone	Hanover stone	Algoma Co.'s stone
	per cent.	per cent.	per cent.
Silica	1.30	0.40	1.50
Alumina and iron oxide	1.20	0.30	0.50
Lime	31.00	54.50	53.50
Magnesia	19.50	0.54	0.80
Sulphur	0.15	0.028	....

COKE

	Algoma Co.'s coke	Hamilton coke, air dried	Composition of ash in sample 2
	per cent.	per cent.	per cent.
Fixed carbon	88.56	86.62	Silica.......5.86
Volatile matter	0.96	1.16	Alumina and iron oxide......5.02
Ash	10.48	12.04	Lime........0.70
Sulphur	0.75	1.07	Magnesia....0.34
Phosphorus	0.018	....	Iron........0.74
Moisture	....	0.18	....

DESCRIPTION OF PLANT DESIGNED BY THE VOLTA COMPANY FOR SMELTING IRON ORES IN OPEN PIT FURNACES

Ten furnaces of 4,000 kv-a. each. Each with three 24-inch electrodes. The furnace shell 16 feet long by 8 feet wide by 6 or 7 feet high. Placed 40 feet apart, centres. The furnace building 456 feet long with a span of 55 feet and a 22-foot rise. A lean-to on one side, 17 feet wide, for the transformers.

The building would be extended 220 feet at one end for a storage and mixing department. At the other end a pig-moulding machine would be installed. The molten metal would be brought to the machine by an overhead crane, and the pigs would be dumped into cars, or on a dump heap. Two 10-ton cranes would be provided for handling the raw materials and the molten metal.

The raw materials are carried by a belt conveyor to overhead bins which discharge at points convenient for each furnace.

A 10-ton travelling derrick and a locomotive are provided for handling the materials in the yard.

The cost of the plant has already been given.

7. THE OPEN HEARTH AND BESSEMER PROCESSES OF STEEL-MAKING

By J. G. Morrow

The Open Hearth Process

The open hearth process of steel-making is divided into two classes: acid and basic. These designations apply to the slags used, which in turn determine the bottom material. Aside from the nature of the bottom, the furnace structure is identically the same.

Briefly, an open hearth furnace may be divided into four parts: the furnace itself, built of silica brick, bound with steel stays in such a way that expansion and contraction may be taken care of; the regeneration chambers filled with brick, laid in such a way that the hot gases must pass through countless small openings; the valves for reversing the direction of the flow of the gases; and the stack for carrying away the spent gas.

In operation, the direction of flow is reversed every fifteen or twenty minutes, so that while air for combustion is being preheated in one generator, the products of combustion are giving up their sensible heat to the mass of brick work in the other. By this means a temperature high enough to melt steel is easily obtained in the furnace proper, the real problem being to so control the temperature that the furnace structure itself will not suffer damage.

In the basic process, which is the predominate one, the bottom is built up of magnesite brick, over which grain magnesite is scattered in thin layers, each layer being completely fused before the next is added. In acid practice, clay brick and the purest obtainable silica sand are used in the same fashion.

The capacity of these furnaces will run anywhere from 15 to 20 tons for a small foundry furnace, and to 100 tons in the case of a modern basic furnace for ingot production.

A basic furnace is charged with limestone, scrap, and pig iron (or hot metal) in the order named. The metallic charge would be roughly 40 per cent. iron and 60 per cent. scrap, and in the neighbourhood of ten hours would be consumed in melting and working the heat into shape for tapping. In this process, phosphorus is easily eliminated, and iron totally unsuited for acid Bessemer work is made into steel far superior to any Bessemer product. While some sulphur may be worked out it is a doubtful quantity, and to avoid trouble the sulphur content of the charge is best kept within the limits desired in the finished product.

The acid open hearth, like the acid Bessemer, requires the best raw material. The phosphorus must be low in the iron as it is unaffected by the refining operation, and only the best and cleanest heavy melting scrap can be used in conjunction with the iron.

The chief advantage of either method of open hearth steel-making as compared with the Bessemer process, lies in the fact that, barring accident, the metal may be held under observation in the furnace until it is definitely assured that the refining operation has been complete in every detail.

The nature of the acid method is such that it is sometimes considered that a slightly better grade of steel is produced than that ordinarily made on a basic bottom. At the end of the acid operation, silica from the slag is reduced and goes into the metal as silicon, thereby thoroughly deoxidizing the metal in the furnace, while in basic practice no such reducing action can be obtained, and deoxidation must be carried on by additions of ferro-silicon, ferro-manganese, or other powerful reducing agents.

The foregoing would not apply to an electric furnace with a basic bottom, as the high temperature obtainable in an electric furnace permits the use of a reducing slag in the nature of a calcium carbide.

The Bessemer Process

The Bessemer process of steel-making was patented in 1856, at which time England was the leading steel producer of the world with an annual output of 50,000 tons, selling at from $250 to $300 a ton. The revolution wrought by the Bessemer innovation is clearly seen when the above figures are compared with those of 1882, when the output had jumped to 4,000,000 tons and the price had fallen to $40 a ton.

The modern converter used for steel ingot production is of 15 or 20 tons capacity, and will convert the above amount of molten pig into steel in about twelve minutes. The vessel is mounted on trunnions which permit it to be tipped at will, and it consists of a pear-shaped steel shell with a quickly-detachable bottom. This last point is very important as the blast enters through small holes in the bottom of the vessel, which is consequently subject to severe erosion and must be replaced every twenty to twenty-five heats. In modern practice this change can be made in about twenty minutes.

The lining of the vessel may be either acid or basic, depending on what the available raw materials are, but as the basic Bessemer has found little application, and that only in Europe, the acid process in which the vessel is lined with gannister, will alone be considered here. Standard Bessemer iron (U.S.) has the following analysis:—

	per cent.
Silicon	1.00 to 2.00
Phosphorus	Not over .10
Sulphur	Not over .05

In this process, no sulphur or phosphorus is eliminated, and therefore these elements have to be low in the iron. All the heat needed to produce the molten steel is generated through oxidation of the silicon, manganese, and carbon in the iron charged, the blast being cold. Preparatory to charging, the vessel is turned down on its side and the iron poured in. A gentle blast is then turned on and the vessel turned up. At this stage care must be exercised or the loss in metal, due to slopping, will be heavy. However, after the slag period when the silicon and manganese are oxidized, the metal is covered with a heavy viscous slag and the blast may be safely increased to its maximum. It is during this stage, known as the boil, that the Bessemer process is most spectacular. An intense white flame issues from the vessel as the carbon in the iron is oxidized to CO.

The success of the process lies entirely in the skill of the blower who watches this flame. From it he judges the temperature of the metal and the progress of the blow. If the metal is too hot, steam is turned into the blast, or scrap thrown in the vessel; if too cold, the vessel is tipped so that some of the tuyères are exposed. This results in complete combustion of carbon to CO in the vessel, and raises the temperature.

When the carbon is eliminated, the flame drops; the vessel is then turned down on its side and the blast turned off. The metal is recarburized either in the vessel or ladle and poured into ingots.

The slag made is essentially a silicate of iron and manganese containing about 50 per cent. SiO_2, 30 per cent. MnO, and 15 per cent. FeO. It will run about 7 or 8 per cent. of the original charge, and the total metallic loss will be from 8 to 12 per cent.

Owing to the limited supply of low phosphorus iron ore and the introduction of the basic open hearth process, the only Bessemer extension in recent years has taken place in an effort to speed up the open hearth furnace by preliminary refining in the converter. Remarkable as the Bessemer process was, and is, it has been pushed aside by an ever-present demand for quality product.

PART II

IRON ORE DEPOSITS OF ONTARIO

The iron ore deposits of Ontario are very numerous, but few of those so far discovered are of quality and size to permit of the production of large quantities of merchantable ore.

During the period 1867 to 1888 there was mined in Eastern Ontario half a million tons of ore, mostly magnetite, that was shipped to smelters without preliminary treatment except rough cobbing. Most of the Helen hematite ore also went directly to smelters from the mine. Aside from these shipments, Ontario's production has been from ore which was necessarily concentrated or roasted before being marketed.

In the following descriptions of iron ore occurrences it will be noted that there are no large developed deposits of merchantable ore. Descriptions are given of some promising deposits and also of a large number of deposits which are of no present or prospective value except as proof of the existence of iron-bearing formations in the several localities.

The only large developed deposit of merchantable hematite, the Helen, has been worked out. Similar ore has been found at the Josephine, but has not yet been developed.

The siderite deposit that looks most promising is the New Helen. The chief producer of siderite up to the present is the Magpie. There are similar siderite deposits at the Bartlett and neighbouring properties, in Michipicoten.

Magnetite deposits are numerous, and many have been worked. The largest developed one is the Moose Mountain, which has received much attention. In Eastern Ontario there are several magnetite deposits which are worthy of consideration as sources of ore which could be marketed after concentrating and sintering. A larger, but highly sulphurous magnetite deposit is that at Atikokan. On the following pages will be found descriptions of many deposits of magnetite. Of those that are high enough in iron, many contain sulphur or titanium in objectionable quantities. The Moose Mountain and some of the Eastern deposits are low in impurities, but also low in iron and require fine grinding for concentration.

The descriptions of iron ore occurrences in Ontario which follow are, for the most part, those summarized in a report entitled "Iron Ore Occurrences in Canada," published by the Department of Mines, Ottawa, 1917.

A. IRON MINES

1. ATIKOKAN IRON MINE

Owners: Atikokan Iron Company, Limited, Port Arthur, Ont.

The Atikokan iron mine is located on mining locations E10, E11, and E12, on the Atikokan river, in the District of Rainy River. A spur 3 miles long connects the mine with the main line of the Canadian National railway at Iron Spur, 128 miles west of Port Arthur.

The Atikokan iron deposits were discovered in 1882 by Jim Shogonosh, an Indian trapper in the employ of Mr. G. McLaurin, of Savanne, Ont. The latter interested Messrs. McKellar Bros., of Fort William, who applied for and acquired from the Government what are now known as mining locations E10 and E11. In 1905 the property was taken over by the present owners, the Atikokan Iron Company, Limited, of Port Arthur.

With the exception of a trench cut across the ore-bearing ridge in 1887, no development work was done till 1900, when a tunnel 5 by 6 feet was driven through the hill, a distance of 284 feet. In 1901, six diamond-drill holes were put down. The tunnel was enlarged in the years 1907 and 1911. In 1911 and 1912, four additional tunnels were driven into the hill. Three exploratory shafts were started in 1912. One was discontinued at a depth of 47 feet, but Nos. 2 and 3 were sunk 150 and 126 feet, respectively, and from the bottom of each of the latter a drift was driven across the ore-bearing zone. Since the completion of this work in 1913 all operations at the mine have been suspended.

Mining operations to supply the company's blast furnace at Port Arthur commenced in 1907 when a small output was shipped. The mine was again operated in 1909, 1910, and 1911. The total quantity of ore shipped from the mine was 90,680 tons.

The most conspicuous feature of the Atikokan property is a steep, narrow hill with a length of 3,800 feet, a maximum width of 400 feet, and a maximum elevation above the swamp, which surrounds it on all sides, of 100 feet. This hill is composed chiefly of dark basic rocks with which are interbedded irregularly-shaped, roughly lenticular, overlapping bodies of magnetite, some of which are impregnated with sulphides.

The irregularities in width and in chemical composition of the ore lenses are illustrated by the following information secured from exploratory working.

Tunnel A is the most westerly of those driven in the ore-bearing hill. It cuts 3 lenses of ore with widths respectively of 7, 26, and 8 feet. The analyses of the ore in these lenses show the following range:—

	Per cent.
Iron	45.1 to 51.25
Silica	4.9 to 15.40
Sulphur	14.9 to 18.80
Phosphorus	0.009 to 0.06

Tunnel B is located 1,185 feet east of tunnel A. It cuts 6 lenses of ore with widths of 12, 8, 24, 22, 9, and 5 feet, respectively. The analyses of the ore showing in these lenses range as follows:—

	Per cent.
Iron	45.9 to 59.0
Silica	8.3 to 19.4
Sulphur	2.2 to 12.3
Phosphorus	0.9 to 0.85

No. 1 shaft, 250 feet west of the entrance to B tunnel, was sunk 47 feet in pyritic ore of the following average composition:—

	Per cent.
Iron	55.33
Silica	4.46
Sulphur	19.93
Phosphorus	0.105

Tunnel C (the original exploratory tunnel) is 450 feet east of B tunnel. This cuts 2 ore lenses with widths of 47 and 42 feet, respectively. The ore shipped from the first-mentioned lens was of the following average composition:—

	Per cent.
Iron	60.00
Silica	8.50
Sulphur	2.01
Phosphorus	0.11

The average analysis of the ore cut in the northerly lens is as follows:—

	Per cent.
Iron	47.68
Silica	17.51
Sulphur	2.30
Phosphorus	0.193

Drill hole No. 4, located only 40 feet west of C tunnel and dipping north at 45 degrees, cut 19 bands of ore, only two of which have a greater horizontal width than 10 feet, and thirteen of which are less than 5 feet wide.

No. 2 shaft was sunk 100 feet east of the entrance to C tunnel, and a drift from this at a depth of 150 feet and parallel to C tunnel cut 6 lenses of ore with widths of 8, 18, 24, 13, 12, and 9 feet, respectively. The analysis of the sections of the lenses cut in the drift show the following range:—

	Per cent.
Iron	48.36 to 59.20
Silica	8.40 to 18.17
Sulphur	0.98 to 4.41
Phosphorus	0.06 to 0.13

Tunnel D located 450 feet east of C tunnel cuts 2 lenses of ore with widths of 40 and 35 feet, respectively. The ore mined from the first or southerly one averaged as follows:—

	Per cent.
Iron	59.57
Silica	8.41
Sulphur	2.17
Phosphorus	0.11

The section of the northerly lens exposed in the tunnel is of the following composition:—

	Per cent.
Iron	59.40
Silica	8.10
Sulphur	0.61
Phosphorus	0.041

Tunnel E is located 510 feet east of tunnel D. This cuts 2 lenses of ore with widths of 47 and 17 feet, respectively, separated by 19 feet of rock. The average analyses of the sections of ore exposed in the tunnel are as follows:—

	South lens per cent.	North lens per cent.
Iron	48.86	56.18
Silica	15.90	11.05
Sulphur	12.90	1.97
Phosphorus	0.169	0.157

From No. 3 shaft, sunk at the entrance to tunnel E, a drift was driven northwards parallel to tunnel E at a depth of 126 feet. This cut only 1 ore lens, 39 feet wide, the first 35 feet of which is of the following composition:—

	Per cent.
Iron	48.84
Silica	12.52
Sulphur	15.80
Phosphorus	0.23

The ore as exposed in the workings is a hard, dense magnetite, difficult to mine and of a refractory nature. Associated with it are pyrite and pyrrhotite in varying proportions, also a little chalcopyrite. Phosphorus runs above the Bessemer limit, and nickel and copper are present in minute quantities.

The bulk of the ore shipped was taken from an open cut about 300 feet long, 40 feet wide, and 60 feet deep, on the south side of the hill at C tunnel. Smaller quantities have come from a small open cut at the south entrance of D tunnel, and from exploratory work.

The average analysis of the ore shipped was as follows:—

	Before roasting per cent.	After roasting per cent.
Iron	59.85	60.24
Silica	8.68	8.54
Sulphur	2.01	0.66
Phosphorus	0.11	0.11
Alumina	1.51	1.55
Lime	3.00	3.15
Magnesia	2.54	2.59
Manganese	0.11	0.11
Copper	0.12	0.12
Nickel	0.11	0.11
Titanium	None	None

Because of its objectionable sulphur content, all this ore has to be roasted to prepare it for use in the blast furnace.

The average cost per gross ton of the output of ore f.o.b. cars mine, including a charge of 25 cents per ton for depreciation, was $1.33. Once underground mining has to be undertaken, the cost of ore on cars will be increased, but the operators estimated the cost as low as $1.60 per ton.

As regards the quantity of ore available for mining here, there are without doubt several millions of tons scattered through the ore-bearing zone. But the ore occurs throughout the enclosing rock, in bodies that are very irregular both in outline and in distribution, causing the relative proportion of rock and ore over a given width of the ore belt to vary greatly within even short distances. These considerations made an estimate of tonnage of ore recoverable almost impossible. In addition, the variable, and sometimes very high sulphur content, a matter seriously affecting the value of the ore, would have to be taken into consideration in any estimate of tonnage of *commercial* ore.

The owners, through the manager, Mr. J. Dix Fraser, furnished in 1915 the following estimate of tonnage of ore proven:—

	tons	tons
Low Sulphur Ore in Sight:—		
(1) Top of hill to 150-foot level	2,453,405	
(2) 150-foot level to bottom of drill holes	2,414,606	
Total low sulphur ore		4,868,011
High Sulphur Ore in Sight:—		
(1) Top of hill to 150-foot level	2,480,454	
(2) 150-foot level to bottom of drill holes	3,567,018	
Total high sulphur ore		6,047,472
Total ore in sight		10,915,483

In this estimate no mention was made of percentage of sulphur in either grade of ore, but it seems that "low sulphur ore" is meant to include ore running up to 6 per cent. sulphur.

The amount of available ore that will compare favourably in composition with the ore shipped, that is containing about two per cent. sulphur, is relatively small. According to one estimate there is above the tunnel level about 500,000 tons of such ore, and an equal tonnage of ore higher in sulphur. The exploration by shafts, cross-cuts, and drill holes shows an additional large tonnage below the tunnel level; but less than half of this is low in sulphur.

REFERENCES: J. Dix Fraser for Atikokan Iron Company, Port Arthur, Ont., 1914.
F. Hillé, Mines Branch, Ottawa, Report No. 22.
A. H. A. Robinson, Mines Branch, Summary Report, 1914.
Annual Reports, Ontario Bureau of Mines, 1900-1915, inclusive.

2. HELEN MINE (HEMATITE DEPOSIT)

Owners: Algoma Steel Corporation, Limited, Sault Ste. Marie, Ont.

The band of iron formation on which Helen mine is located has a length of 1¾ miles, and for three-quarters of a mile the width averages about 1,200 feet. It is composed chiefly of cherty and granular silica, usually massive but in places slightly banded. In many places it has been badly crushed and brecciated. In subordinate quantities there occur segregations of siderite, goethite, and hematite, which, exploration has shown, lie exclusively along the south side of the range. With the chert, granular silica, and siderite, there is usually associated more or less pyrite, and in places, deposits of pyrites of merchantable grade and of considerable size exist.

The Helen property was acquired in 1898 by E. V. Clergue for the Lake Superior Power Company. It was rapidly developed. A railroad was constructed from the mine to Michipicoten Harbour, and shipments began in 1900.

Helen mine is situated on mining claims Nos. 68 and 69, in the southern part of township 29, range XXIV, in the District of Algoma. It is 11½ miles distant by rail from Michipicoten Harbour on Lake Superior, where is located the ore dock of the Algoma Central and Hudson Bay railway, at which lake vessels of 21-feet draft may tie up.

This mine has to its credit the largest iron ore production of any mine in the Dominion of Canada, the shipments of iron ore from the commencement of mining operations in 1900 to the end of 1918 having been 2,823,369 short tons.

The Helen mine was closed down on April 16th, 1918. Some pyrite was shipped from stock piles in 1919 and 1920.

The total shipments from the Helen mine from the beginning of operations up to 1919 were as follows:—

	Short tons
Hematite	2,780,236
Tailings	43,133
Pyrites	51,930
Total	2,875,299

The ore shipped was classed according to iron and sulphur content. Grade Helen No. 1 was lower in sulphur than Helen No. 2. Average analyses of ore shipped in 1914 were as follows:—

	Helen No. 1 per cent.	Helen No. 2 per cent.
Iron	56.79	57.76
Silica	6.16	5.90
Sulphur	0.264	0.391
Phosphorus	0.095	0.092
Alumina	0.90	0.88
Lime	0.24	0.23
Magnesia	0.152	0.140
Manganese	0.17	0.165
Moisture	4.00	4.00

The owners, the Algoma Steel Corporation, supply the following figures as to cost of ore f.o.b. cars at the mine, and prices realized for product at the same point:—

COST OF ORE F.O.B. CARS AT MINE, INCLUDING 30 CENTS PER TON FOR SINKING FUND

Year ending	June 30th,	1909	$1.93
do	do	1910	1.93
do	do	1911	2.18
do	do	1912	2.69
do	do	1913	3.10
do	do	1914	2.23

SELLING PRICE PER TON F.O.B. CARS AT MINE

Calendar year	1909	$3.09
do	1910	3.00
do	1911	2.72
do	1912	2.95
do	1913	2.85
do	1914	2.33 (high sulphur)

The mine was developed from two shafts. No. 1 shaft, sunk to the sixth level, a depth of 435 feet, was used for cage and ladderway. No. 2 shaft, started from about the same level as No. 1 shaft, was sunk as a two-compartment shaft to the sixth level, and as a four-compartment shaft to the ninth level at a depth of 651 feet. In 1912, the portion of No. 2 shaft above the fourth level was abandoned, and a new incline was driven from there to surface, making the total depth of the present No. 2 shaft 821.7 feet.

Probably about 45,000 feet of drifting, cross-cutting, and raising was done in opening up the mine on the eight levels which have been worked. Prior to 1904, diamond drilling to the extent of 3,425 feet was done.

The main ore body lay at the eastern extremity of a small lake called Boyer lake, which has been pumped out. In shape the deposit was roughly elliptical, the longer axis, on the upper levels, being 700 feet and the shorter 200 feet. As greater depth was reached the major axis decreased in length, but at the same time the minor axis increased, with the result that about the same floor area of ore existed on each level except the eighth, where it is probably less than half as large as on the levels above. The ore body had a pitch of about 60 degrees to the northeast. The vertical extent was about 700 feet.

On the south side, the ore body was bounded by country rock to the fifth level, and from that to the eighth by siderite; on the east it merged into lean ore; on the north it was bounded by a zone of iron-stained silica, succeeded by brecciated chert; and to the west it was bounded by a white to yellowish clayey dike, which, away from the ore body, is really a medium-grained diabase. This dike appears to form the barrier in the iron formation against which the ore body was deposited.

An interesting, though unfortunate feature of this deposit was the presence in it of pockets of pyritic sand varying in size from those containing a few cubic feet to others varying from 30 to 40 feet in their greatest dimensions. These pockets were not numerous on the first level, but on succeeding levels the pyritic zone increased in size, thus raising the sulphur content of the ore hoisted, and resulting in a large tonnage of ore having to be left unmined.

To the west of the clayey dike, lay a smaller ore body first picked up on the third level at a depth of 280 feet. This has been worked on the third, fourth, fifth, and sixth levels. A considerable proportion of this ore was of Bessemer grade (in marked contrast to that of the main ore body), but on the lower levels the ore was badly contaminated with pyrites.

The upper portion of the ore body was mined in benches, and the ore was loaded into railway cars by steam shovels. From track level to the second level, at a depth of 164 feet, the greater portion of the ore was handled by milling methods. On the third, fourth, fifth, and sixth levels the ore was extracted by underhand stoping methods, pillars being left at intervals of about 50 feet to support the "back." On the seventh and eighth levels the ore was won by slicing and caving from sub-levels.

The siderite mine at the Helen property is commonly referred to as the New Helen. This siderite deposit has been explored by diamond drilling and by a tunnel. The ore body stands nearly vertical. The width at surface ranges from 46 to 272 feet and averages 165 feet. Ore is exposed at surface in 13 trenches and cut below by 18 drill holes, aggregating 17,761 feet of drilling. It is estimated that ten million tons of ore can be recovered from the part of the deposit above tunnel level. There is here also an additional 1,000,000 tons which would be high in sulphur. Below the tunnel level, there is several times these quantities of the two grades of ore. There is probably 100,000,000 tons in all, of which about 70,000,000 tons will probably average less than two per cent. sulphur.

REFERENCES: A. P. Coleman and A. B. Willmott, Ontario Bureau of Mines, 1902, pp. 152-165.
A. P. Coleman, Ontario Bureau of Mines, 1906, p. 187.
R. W. Seelye, Journal of Canadian Mining Institute, 1910, pp. 121-134.
Plans and records furnished by Mines Department of Lake Superior Corporation, Sault Ste. Marie, Ont., 1914. (George S. Cowie, Secretary.)
A. L. Parsons, Ontario Bureau of Mines, 1915, p. 202.
Annual Reports, Ontario Bureau of Mines, 1900-1915, inclusive.

3. MAGPIE MINE

Owners: Algoma Steel Corporation, Limited, Sault Ste. Marie, Ont.

The Algoma Steel Corporation's Magpie mine is located in the southeast quarter of township ship 29, range XXVI, in the District of Algoma. It is connected by a nine-mile spur with the Michipicoten division of the Algoma Central and Hudson Bay railway, by which access is had to Michipicoten Harbour on Lake Superior, 26 miles distant, and to Sault Ste. Marie, 182 miles distant.

The claims comprising the Magpie mine property were staked in 1909 on several showings of magnetite. Exploration by trenching, stripping, test-pitting, and diamond drilling was undertaken the same year, and was continued till the fall of 1910, this work showing the deposits to consist essentially of siderite, portions of which had been altered to magnetite.

In 1910 the sinking of a four-compartment shaft was commenced, and in 1911 the erection was undertaken of a roasting plant for the production of a marketable ore from the siderite, which had been shown to have an iron content of about 35 per cent., and an objectionable amount of sulphur.

The roasting plant was put in operation in December, 1912, and was operated till October, 1913, when it was dismantled to be replaced by a plant designed along lines suggested by the experience of the previous ten months. The new roasting plant went into operation in May, 1914, and continued till October 31st, when mining operations were suspended indefinitely on account of the depression in the iron and steel trade. In May, 1915, mining operations were resumed, and the roasting plant, with some modifications, was again put in commission.

The Magpie operations were discontinued on March 8th, 1921. Since that time the mine has remained closed down. The drifting had been carried 335 feet west and 350 feet east on the fifth level.

Shipments from the Magpie during the years 1913-1921 were:—

	Tons
1913	22,327
1914	109,838
1915	129,722
1916	210,522
1917	197,561
1918	168,906
1919	189,962
1920	106,241
1921	58,401

The ore in this deposit is a hard, dense, fine-grained siderite, most of which is more or less altered to magnetite. The colour varies from pale yellow, through grey, to black, according to the proportion of magnetite present. Pyrite is rather plentifully present, always in such an amount as to give an undesirable sulphur content. A good proportion of this is scattered in small, almost indiscernible grains throughout the siderite, and quite a proportion is in small pockets and streaks, the most of these, however, being confined to a zone along the south wall.

An average of the analyses of 157 samples taken during development of the 1st and 2nd levels is as follows:—

	Per cent.
Iron	36.79
Silica	5.70
Sulphur	0.78
Phosphorus	0.012
Manganese	2.00 to 3.00
Loss on ignition	28.01

Such an ore, of course, requires calcination and desulphurization before it is fit for blast furnace use.

The other ore bodies are of smaller size and inferior quality, and hence have not been explored to any considerable extent.

The ore bodies stand about in the vertical and have a general east and west trend. They are enclosed in Keewatin rocks, greenstone being found usually on the north, and quartz-porphyry schist on the south.

The following analyses show the average composition of the roasted ore shipped in 1914 and 1916:—

	1914 per cent.	1916 per cent.
Iron	50.60	50.10
Silica	9.39	9.14
Sulphur	0.25	0.136
Phosphorus	0.011	0.013
Alumina	1.02	1.28
Lime	8.79	7.96
Magnesia	7.05	8.04
Manganese	2.71	2.74
Loss by ignition	Nil	Nil

A description of the Magpie roasting plant will be found on page 57.

The method of mining at the Magpie has been fully described by Mr. A. Hasselbring in a paper presented at a meeting of the Canadian Institute of Mining and Metallurgy in 1917.

REFERENCES: E. T. Corkill, Ontario Bureau of Mines, 1912, p. 113.
E. T. Corkill, Ontario Bureau of Mines, 1913, p. 106.
T. F. Sutherland, Ontario Bureau of Mines, 1914, p. 124.
Jas. Bartlett, Ontario Bureau of Mines, 1915, p. 105.
D. E. Keeley, Porcupine Branch, Canadian Mining Institute, 1914.
Plans, records, and information supplied by Mines Department, Lake Superior Corporation, Sault Ste. Marie, Ont. (Geo. S. Cowie, Secretary), 1915.
A. Hasselbring, Trans. Can. Inst. Min. Met., 1917, pp. 321-332.
T. F. Sutherland, Reports of Inspector of Mines, Ontario.

4. MOOSE MOUNTAIN MINE

Owners: Moose Mountain, Limited, Sellwood, Ont.

Property and Location.—The property of Moose Mountain, Limited, includes a number of low-grade iron ore deposits in an area of about 4 square miles, which extends from lot 6, concession III of the Township of Hutton, District of Sudbury, northwesterly for 4½ miles into lot 1, concession VI, of Kitchener township. The greater number of these deposits are grouped around the village of Sellwood.

Sellwood lies about 25 miles north of Sudbury, its nearest important centre, and is connected by a short branch line with the Toronto-Port Arthur line of the Canadian National railway, at Sellwood Junction. A few miles south of the French river, a six-mile spur from the main line of the Canadian National has been constructed to Key inlet on the Georgian bay, making a rail haul from Sellwood to Key Harbour of 82 miles.

History.—Although the existence of deposits of banded iron formation here had been known since the early nineties, it was only in 1901 that exploration of these works was undertaken. The first development work was done in 1906, on No. 1 deposit, and during 1907 a small crushing plant was installed at that point. The first shipment was made in 1908 when railway communication was established. The unfavourable reception this ore was accorded because of its low iron content, led to the installation early in 1909 of a magnetic cobbing plant. Sufficient success attended the cobbing process to induce the owners to erect an enlarged cobbing plant, which was completed in 1910. The enlarged plant was in operation from August, 1910, to May, 1911, when it was closed down owing to unsatisfactory market conditions and complaints made by the buyers that the ore contained too high a percentage of fines. It was, therefore, necessary to screen the ore before further shipment could be made. This resulted in a considerable loss of magnetite in the fines.

The cobbing plant was put in operation again in 1912, and was operated until June, 1914. The fines from this plant since 1912 have been taken care of in a Gröndal concentrating and briquetting plant, erected that year for the purpose of treating the low-grade siliceous ore comprising the major proportion of the company's ore reserves. Experimental operations have been carried on intermittently at this point since 1912.

Mining operations were resumed in May, 1916, and additional plant was installed. This included a briquette press in which the concentrates were made into large briquettes about the size of ordinary building brick and weighing about 7½ pounds.

Operations continued in 1918, when 54,291 tons of ore were raised and 26,385 tons of briquettes made and shipped. Additional plant was added, and, in 1919, the output was 38,099 tons of briquettes. The mine and mill were closed down on November 29th, 1920, since which time the only shipments have been from the stock piles. An account of the treatment of Moose Mountain briquettes in the blast furnace will be found in Chapter XII of this report.

Ore Deposits.—The ore deposits lie in a series of metamorphic schists of Archean age, the chief constituents of which are hornblende, chlorite, feldspar, and quartz. The more basic members of this series are prevailingly dark green in colour, owing to the large amount of hornblende and chlorite present; while others, chiefly made up of feldspar and quartz, are of a lighter colour. The deposits have been upturned, faulted, and folded together with these schists; their general strike and dip being, therefore, conformable to that of the latter, which generally is in a northwesterly direction, with a dip varying from 70 to 85 degrees towards the east. Locally, however, where the folding has been very intense, marked divergences in strike and dip frequently occur.

The existence of 11 ore deposits of all grades has been established by surface and diamond-drill exploration and by magnetometric survey. These are divisible into two classes or types:—

Type A (including deposits Nos. 1 and 5) consisting of magnetite associated with hornblende, pyroxene, and epidote.

Type B (including all deposits except Nos. 1 and 5) consisting of fine-grained siliceous magnetite interbanded with siliceous material of both cherty and quartzitic texture.

Because of their irregular mineralogical composition, it is almost impossible to state what is the average iron content of deposits of type A. From them it has, however, been demonstrated by operations extending over a period of several years, that there can be secured by magnetic cobbing a non-Bessemer concentrate running about 55 per cent. iron. A study of the figures cover-

ing ore mined and milled for a two-year period shows that of the ore mined, concentrates constituted 64.3 per cent., dust 10.8 per cent., and tails 24.9 per cent. These figures taken in conjunction with the analysis of the three products, indicate that the average iron content of the ore mined was 43.2 per cent.

Deposits of type B average about 37 per cent. iron, 45 per cent. silica, and 0.055 per cent. phosphorus

Details as to yearly shipments of concentrates (which total 323,049 gross tons to the end of 1915), and average analyses, cost, and selling price of the same, are shown in the following statement:—

YEARLY SHIPMENTS OF CONCENTRATES, 1908-1914

Year	1908	1909	1910	1911	1912	1913	1914
Shipments, gross tons	2,557	26,199	71,784	6,749	49,339	95,518	23,334
ANALYSIS:		%	%		%	%	%
Iron	......	55.45	54.60	......	54.30	55.50	54.45
Silica	......	12.67	14.29	......	14.54	14.15	14.55
Sulphur	......	0.074	0.029	......	0.031	0.027	0.036
Phosphorus	......	0.107	0.091	......	0.099	0.099	0.105
Alumina	......	1.58	1.92	......	1.83	2.03	2.09
Lime	......	3.77	3.82	......	3.97	3.26	4.00
Magnesia	......	3.52	3.64	......	3.04	3.06	2.83
Manganese	......	0.09	0.06	......	0.07	0.08	0.07
Loss by ignition	......	......	0.63	......	0.48	0.42	0.75
Cost f.o.b. cars mine	......	......	......	......	......	$1.6488	$1.7955
Selling price f.o.b. cars mine	$2.60	$2.10	$2.85	$2.35	$1.75	$2.25	$1.90

The cost given for 1913 and 1914 includes exploration and development during the interval under consideration, mining, stoping, tramming underground, pumping, crushing, and milling, but does not include any charge for previous development, nor for superintendence and mine office expenses.

The dust from the No. 1 plant has, during recent years, been ground, concentrated, and briquetted at the Gröndal, or No. 2 plant. Particulars as to shipments of briquettes during 1913 and 1914, and average analyses of the same, are shown in the following table:—

SHIPMENT OF BRIQUETTES AND ANALYSES OF SAME, 1913-1915

Year	1913	1914	1915
Shipments, gross tons	3,013	5,466	1,680
ANALYSES:	%	%	
Iron	63.03	63.02	....
Silica	6.05	6.66	....
Sulphur	0.014	0.012	....
Phosphorus	0.028	0.037	....
Alumina	0.93	1.00	....
Lime	2.00	1.50	....
Magnesia	1.49	1.53	....
Manganese	0.06	0.08	......
Loss by ignition	None	None	....
Selling price f.o.b. cars mine	$4.02	$3.34	....

Freight Rates.—The freight rates existent in 1914 on iron ore shipments from Sellwood were as follows:—

To Sault Ste. Marie, all rail	$1.60
Parry Sound, do	1.00
Deseronto, do	1.55
Key Harbour (including loading into boats to U.S. ports)	.55
Key Harbour (including loading into boats to Canadian ports)	.65

The lake freight from Key Harbour to Lake Erie ports in 1913 was 40 cents, and in 1914 it was 35 cents.

Ore Reserves.—The ore reserves consist of deposits of type A with an area of 71,000 square feet, and those of type B with an area of 3,185,000 square feet. Data for making a reliable estimate of tonnage of either type are insufficient.

As it is evident that only a limited tonnage of concentrates of the grade already produced is still available from deposits Nos. 1 and 5, the owners realize that the problem to be solved is the economical production of a marketable product from deposits of type B. The total area of all deposits is about 3,256,000 square feet. Assuming an average specific gravity of 3.8 for the ore, the deposits, for each 100 feet in depth, should yield about 38,665,000 tons of siliceous ore; and with a proven depth of at least 300 feet for portions of two deposits, it is probable that the figures of tonnage just mentioned may be much below the tonnage of siliceous ore actually available for mining.

Experiments carried out by Moose Mountain, Limited, indicate that 2.1 tons of ore of type B are required to furnish one ton of concentrates averaging 65 per cent. iron. On this basis the ore deposits for each 100 feet of depth would probably yield about 18,500,000 tons of concentrates.

Power.—All the equipment is electrically operated by power brought in over the company's own transmission line from the Wahnapitae Power Company's plant 35 miles distant, the power being paid for at the power company's switch-board at the rate of $16.00 per horse-power per year, based on the peak load.

REFERENCES: W. H. Collins, Geological Survey of Canada, Summary Report, 1912, p. 312.
E. Lindeman, Moose Mountain Iron-Bearing District, Mines Branch, Ottawa, No. 303, 1914.
Fred A. Jordan for Moose Mountain, Limited, Sellwood, Ont., 1914.

5. BLAIRTON MINE

Owners: Canada Iron Mines, Ltd., Trenton, Ont.

The Blairton iron mine is situated on lots 7 and 8, concession I, in the Township of Belmont, Peterborough county. It lies on the shore of the southwest end of Crow lake about 5 miles west of the Village of Marmora, and about 3 miles northeast of Blairton station on the Canadian Pacific railway. The distance from Blairton station to Trenton by rail is 34 miles.

The mine was opened up about 1820, and was operated intermittently till 1875. During these years very considerable tonnages of ore were shipped. In 1908 some diamond drilling was done, and in 1910 thirteen holes, with an aggregate footage of 3,600 feet, were put down. No exploration or development has been done by the present owners.

The Blairton mine, known in the early days as the Big Ore Bed, was operated in a small way to supply the Marmora iron furnaces which were built in 1820 by Charles Hayes. These furnaces were not operated regularly for any length of time, and their consumption was only a few tons a day. The amount of ore mined at Blairton for the Marmora furnaces is not known, but it could not have been very large.

In the period, 1869 to 1873, however, the Blairton was a large producer of ore for export to the United States. The output in this period was probably about 100,000 tons.

The area surrounding the ore bodies is chiefly occupied by hornblende and chlorite schists and crystalline limestone, in contact with diorite. The general strike of the stratified rocks is about N. 15° W., with a steep dip towards the east.

The ore deposits consist of magnetite, which occurs along the contact of the crystalline limestone and diorite, and is associated with various metamorphic rocks. In some parts of the field the magnetite is found in well-defined layers interstratified with these rocks; in others, finely disseminated throughout the same.

The ore consists of a finely crystalline to massive magnetite, with a gangue of pyroxene and calcite. In the northern ore body there is a good deal of finely disseminated pyrite.

The ore extracted was won from three open pits, the Lake pit on an ore body close to Crow lake, and the Derick and Morton pits on another ore body about 1,000 feet farther south. One of the two latter is 200 feet long, and 150 feet wide, and is reported to be 125 feet deep. All the pits are now filled with water.

No record of the total tonnage of ore shipped is now available, but the amount is estimated to have been from 250,000 to 300,000 tons. The average composition of these shipments is not known, but it appears from the piles of waste ore on the property that only an ore of high iron content was shipped. An average sample across the north end of the Lake pit taken by E. Lindeman in 1911 gave the following analysis:—

	Per cent.
Iron	50.10
Silica	9.88
Sulphur	1.42
Phosphorus	0.046
Alumina	1.73
Lime	3.52
Magnesia	1.64
Titanium dioxide	0.10

To transport ore from the mine it would be necessary to build a railway spur 6 miles long to the Central Ontario railway. The freight rate to Trenton would probably be about 40 cents per ton.

The owners, through their manager, Mr. W. J. McLaughlin, furnish the following figures relating to tonnage and composition of ore reserves:—

TONNAGE AND COMPOSITION OF ORE RESERVES

Deposit	Dimensions			Probable ore	Analysis		
	Length	Width	Depth		Iron	Sulphur	Phosphorus
	feet	feet	feet	long tons	%	%	%
Lake pit	600	200	300	1,800,000	51.80	0.824	0.018
Derick pit	300	100	300	500,000	54.20	0.340	0.010

There is a small amount of mining equipment on the property, but it is all obsolete and would have to be replaced if mining operations were undertaken.

REFERENCES: R. H. Flaherty, Port Arthur, Ont., 1904.
E. Lindeman, Mines Branch, Ottawa, Publication No. 184, p. 9.
W. J. McLaughlin for Canada Iron Mines, Limited, Trenton, Ont., 1914.

6. BELMONT (OR LEDYARD) MINE

Owners: The Canadian Furnace Company, Limited, Port Colborne, Ont.

The Belmont iron mine is situated on lot 19, concession I, of Belmont township, County of Peterborough, about 8 miles northwest of Marmora. It is connected with the Central Ontario railway by a branch line known as the Ontario, Belmont and Northern railway. The distance from the mine to Trenton, on Lake Ontario, by rail, is about 39 miles.

This property was operated many years ago, ore being extracted from No. 1 and No. 2 (or Nichol) pits. In 1911 the former had a length of 200 feet, a width varying from 40 to 70 feet, and a depth of from 3 to 20 feet; and the latter (located 100 feet southeast of No. 1) had a length of 55 feet, a width of 40 feet, and a depth of 5 to 6 feet. Six diamond-drill holes put down in 1906, are said to have proven 200,000 tons of concentrating ore.[1]

In 1911 development work was resumed after a lapse of several years. A 3-compartment shaft, started that year about 15 feet north of No. 1 pit, had reached a depth of 260 feet early in 1914, when mining operations were discontinued. Levels were opened from this shaft at depths of 100, 170, and 230 feet. In 1913 the Mines Inspector reported that the ore body appeared to be widening at depth and the grade of the ore improving.

The character of the iron-bearing formation varies considerably. In some places it consists of almost pure magnetite, in others of a mixture of magnetite and gangue minerals, chiefly pyroxene and chlorite; in other places the latter minerals prevail almost to the exclusion of the magnetite. Iron pyrites is frequently seen throughout the ore. The ore body lies along a contact between crystalline limestone and diorite.

An analysis of an average sample taken from the north end of No. 1 pit by E. Lindeman in 1911 is given herewith:—

	Per cent.
Iron	51.20
Silica	12.10
Sulphur	0.34
Phosphorus	0.032
Lime	4.87
Magnesia	3.93
Titanium	0.10

Since the resumption of mining in 1911 the shipments have aggregated 5,746 short tons, the shipment by years being as follows: 126 tons in 1911, 28 tons in 1912, and 5,592 tons in 1913.

Judging from the magnetometric survey, confirmed by a few natural exposures, the area within which the ore is likely to occur may be roughly estimated at 4,300 square feet, but a large percentage of this area is undoubtedly occupied by barren rock.

REFERENCES: B. F. Haanel, Report of Superintendent of Mines, Ottawa, 1906, p. 5.
W. W. J. Croze for R. H. Flaherty, Port Arthur, Ont., 1906.
E. T. Corkill, Ontario Bureau of Mines, 1912, p. 158.
E. T. Corkill, Ontario Bureau of Mines, 1913, p. 134.
T. F. Sutherland, Ontario Bureau of Mines, 1914, p. 171.
E. Lindeman, Mines Branch, Ottawa, Publication No. 184, 1913, p. 10.

[1]W. W. J. Croze.

7. BESSEMER MINES

Owners: Canada Iron Mines, Limited, Trenton, Ont.

The Bessemer property includes lots 2, 3, 4, and 5, concession VI, and lot 1, concession VII, in the Township of Mayo, County of Hastings. A railway spur, 5 miles long, known as the Bessemer and Barry's Bay railway connects the mine workings with the Central Ontario railway at L'Amble, which is 78 miles north of Trenton, Ont., where is located a magnetic concentrating plant owned by Canada Iron Mines, Limited.

The Bessemer and other ore deposits in this locality were first exploited by Mr. H. C. Farnum, who in 1902 organized the Mineral Range Iron Mining Company, which assumed the ownership of them. By this company the properties were opened and shipments of ore were made in 1902, 1903, 1906, and 1907.

In February, 1908, the Canada Iron Furnace Company, Limited, leased the properties of the Mineral Range Iron Mining Company and operated them till May, 1910, when they surrendered their leases. The mines then lay idle till 1911, when the properties were acquired by the Canada Iron Mines, Limited, who operated them in 1912 and 1913 to supply their concentrating plant at Trenton. Since 1913 the mines have been idle.

The ore deposits occur as isolated lenses of varying extent, associated with a limestone-amphibolite series, along or adjacent to a granite contact.

The best quality of the ore averages about 54 per cent. iron, but considerable cobbing has to be done in order to keep it up to that standard, as a large percentage of the ore does not average more than 40 to 48 per cent. iron.

This latter ore was, until 1911, relegated to the waste dumps, or left in the mine. Locally stringers and patches of iron pyrites are found, but by hand cobbing the ore it was found possible to keep the sulphur down to somewhere near 0.07 per cent. The percentage of phosphorus is very low, averaging from 0.010 to 0.025 per cent.

While the presence of a large number of ore lenses of different size is known, mining operations have been confined to four, which will be described in order from west to east.

Deposit No. 1 on lot 1, concession VII, was developed as an open pit, and a small tonnage of ore has been shipped from it. The ore in this pit is badly mixed with gangue minerals, chiefly hornblende. The presence of a number of small ore lenses adjacent to deposit No. 1 is indicated by a magnetometric survey by E. Lindeman.

Deposit No. 2 is one of a group of deposits on lot 2, concession VI, all of which the magnetometric survey indicates as being very small. It has been developed as an open cut from which a little ore was extracted. The workings show the magnetite to be intermixed with various gangue minerals.

Deposit No. 3 is located on lot 3, concession VI, and is about 1,300 feet east of No. 2. It consists of two open pits, which have been opened up on two ore lenses separated from each other by about 50 feet of gangue rock, through which a small amount of magnetite is disseminated; the smaller pit is 40 by 90 feet and 6 feet deep, and the larger is 60 by 60 feet and 20 feet deep. About 5,000 tons of ore were shipped from these workings.

From the bottom of the larger pit a drill hole was put down, and it was still in ore at 160 feet when discontinued.

In addition to the two lenses opened up, the magnetometric survey indicates, a short distance east and west of these workings, several other deposits, all of which are, however, covered by drift.

Deposit No. 4, the largest and richest of the Bessemer group, is situated on lots 4 and 5, concession VI. According to the magnetometric survey, the total probable length of this deposit may be estimated at about 1,000 feet, the western end extending 400 feet under Little Mullet lake. The average width of the deposit is roughly estimated to be about 50 feet.

This deposit was first worked as an open pit, and from this a very considerable tonnage was extracted, the pit being carried to a depth of 80 feet. Operations in recent years have been conducted from a three-compartment shaft started in 1908. The shaft is inclined to the south-east at 65 degrees, and has a depth of 236 feet; from it levels have been opened at depths of 55 feet, 101 feet, 161 feet, and 236 feet, respectively. On the second level the length of the workings in ore is 495 feet, and on the third it is 525 feet. These workings have proven ore to a greater depth than did the diamond-drill holes put down a few years ago.

The shipments to the end of 1914 are reported as follows:—

From No. 1 deposit...............	700	gross tons	(hand-sorted)
" No. 2 "	1,500	"	"
" No. 3 "	5,000	"	"
" No. 4 "	92,413	"	(hand-sorted and crude)
Total..................	99,613	gross tons.	

The following representative analyses are furnished by Canada Iron Mines, Limited:—

ANALYSES OF ORE FROM BESSEMER MINES

Deposit	Tonnage	Condition	Iron	Silica	Sulphur	Phosphorus
			per cent.	per cent.	per cent.	per cent.
No. 1.......	480	Hand-sorted	49.30	13.30	nil	0.071
No. 2.......	1,500	"	56.00	7.20	nil	0.004
No. 3.......	5,000	"	61.30	8.91	0.042	0.008
No. 4.......	28,000	Crude	49.30	.....	0.465	0.020

The two following analyses were furnished by the Midland Blast Furnace, No. 1 representing ore received from Bessemer mines in 1907, and No. 2 a 25-car shipment received in 1908:—

	No. 1	No. 2
	per cent.	per cent.
Iron............................	54.29	54.00
Silica...........................	9.84	.....
Sulphur.........................	0.062	0.075
Phosphorus......................	0.019	0.022
Alumina.........................	2.02	.....
Lime............................	6.86	.....
Magnesia........................	1.35	.....
Manganese.......................	0.35	.....

The prices received for hand-sorted ore f.o.b. cars mine, in 1906 and 1907, were $1.23 and $2.35. After 1907 the production in each year was used by the same company as was operating the mine, and the prices allowed the mine for its shipments during these years have not been given out.

The mining cost as stated by Canada Iron Mines, Limited, has been $1.55 per ton of crude ore, this figure being made up as follows:—

Exploration and development..................	$0.15
Stoping....................................	.68
Tramming underground.......................	.15
Pumping....................................	.01
Hoisting...................................	.04
Stock-piling, sorting, and loading	.02
Crushing to 2-inch, and conveying.............	.14
General surface.............................	.03
Lighting....................................	.01
Power plant.................................	.21
Superintendence and mine office................	.06
Insurance and taxes..........................	.05
Total..............................	$1.55

The cost of hauling the ore to the Central Ontario railway is approximately 5 cents per ton, and the freight rate on the Central Ontario railway to Trenton is 50 cents per gross ton.

The following figures as to size and probable tonnage of ore of the deposits of the Bessemer property are furnished by the company's manager, W. J. McLaughlin:—

SIZE AND PROBABLE TONNAGE OF ORE OF THE BESSEMER DEPOSITS

Deposit	Length	Width	Depth	Probable ore
	feet	feet	feet	tons
No. 1............................	275	40	300	300,000
No. 2............................	150	40	300	180,000
No. 3a...........................	60	60	300	110,000
No. 3b...........................	125	85	300	310,000
No. 4 north lens..................	380	50	500	....
No. 4 south lens..................	450	40	500	1,000,000
Total probable ore, Bessemer group..........................				1,190,000

"In figuring depth of deposits Nos. 1 and 2, upon which no drilling has been done, we base our assumption upon the fact that a drill hole was put down on deposit No. 3 for a depth of 160 feet, and the bottom was still in ore. We feel that we are conservative in assuming a depth of at least twice that distance, or 300 feet. The result of our diamond drilling in this region has proven to us that the magnetite deposits attain a depth greater than 300 feet.

"In figuring the depth of deposit No. 4, we would say that we have proven the ore to a depth of 236 feet, and on our 160-foot level we find the lenses increasing in width with depth."

The tonnage estimated above is of too low iron content to be marketable as mined, but the owners believe it will concentrate in the ratio of 1.4 tons of crude to 1 of concentrate.

References: Ontario Bureau of Mines, Mines Inspector's reports, 1902-1915, inclusive.
Geo. C. McKenzie, Ontario Bureau of Mines, 1908, p. 221.
E. Lindeman, Mines Branch, Ottawa, Publication No. 184, p. 16.
W. J. McLaughlin for Canada Iron Mines, Limited, Trenton, Ont., 1914.

8. CHILDS MINE

Owners: Canada Iron Mines, Limited, Trenton, Ont.

The Childs mine is located on the south halves of lots 11 and 12, concession IX, in the Township of Mayo, County of Hastings, about 3 miles east of the Bessemer mine, with which it is connected by the Bessemer and Barry's Bay railway.

The property was first exploited by Mr. H. C. Farnum, and later by the Mineral Range Iron Mining Company. Very little work was done on it prior to 1913, when the present owners made a systematic exploration of it and commenced mining operations. Since 1913, the mine has not been in operation.

The ore deposits are found in mica schist, and lime-amphibolite rocks near their contact with granite and other igneous rocks.

The ore is a coarsely-crystalline magnetite, usually intermixed with a gangue of garnet, epidote, calcite, and other minerals.

In 1913 four working faces were stripped and opened on that portion of the deposit lying above swamp level, and ore was broken in open cuts.

Shipments were made only in 1913, when 9,649 gross tons of crude ore were sent to the Trenton concentrator. The average analysis of this ore was as follows:—

	Per cent.
Iron	38.70
Sulphur	0.149
Phosphorus	0.049

The phosphorus exists principally in the gangue, with the result that in the concentrate made therefrom the phosphorus content is much lower than in the crude ore.

Owing to the small tonnage shipped from the property, the cost figures were abnormally high. It is estimated by the owners that with an output of 400 tons per day, the operating cost, including development, will be about $1.00 per ton.

As a result of the surface and diamond-drill exploration the owners believe the probable dimensions of the ore body to be as follows: length 700 feet, width 100 feet, and depth 500 feet. This would yield 3,500,000 tons of ore.[1]

"Diamond drilling has proven the ore to a depth of 250 feet. The lens being 100 feet wide at this depth, it is conservative to assume that it continues twice that distance, or 500 feet."

References: Mines Inspector's Reports, Annual Reports, Ontario Bureau of Mines, 1902-1915, inclusive.
E. Lindeman, Mines Branch, Ottawa, Publication No. 184, p. 19.
W. J. McLaughlin for Canada Iron Mines, Limited, 1914.

9. COEHILL MINE

Owners: Canada Iron Mines, Limited, Trenton, Ont.

This mine is situated on lots 15 and 16, concession VIII, in the Township of Wollaston, County of Hastings, and it is connected by a branch line 7 miles long with the Central Ontario railway at Ormsby junction. The distance by rail from the mine to Trenton is 73 miles.

The mine was opened in the early eighties, and shipments were made from 1884 to 1887, inclusive. It is reported that during this time the quantity of ore mined was between 80,000 and 100,000 tons, about one-third of which was left in stock piles. The high sulphur content of the ore prevented a market being found for it.

Small shipments were made from ore in stock in 1900 and 1909. In 1910 six diamond-drill holes, averaging 450 feet in depth, were put down. The property is now owned by Canada Iron Mines, Limited, but it has not as yet been operated by them.

[1]W. J. McLaughlin.

The main ore body is well exposed on the hill north of the railway track by two open pits. The general trend of the formation is northeast, with a dip of about 50 degrees toward the southeast. The deposit seems to form part of a limestone-amphibolite series, locally enriched in iron by the intrusion of syenite, which cuts the series in the most intricate manner. The ore consists of a fine-grained magnetite, associated with hornblende, pyroxene, and calcite. It has a streaked or stratified appearance parallel to the strike, which is due to the variation in the relative amount of the constituent minerals present. Some streaks are very rich in magnetite, while others are composed of pyroxene and hornblende. The average sulphur content of the ore is high, a considerable amount of pyrite and pyrrhotite being disseminated throughout the ore.

In addition to the main ore body the existence of several others to the north is indicated by Lindeman's magnetometric survey.

The mine was operated as an open cut at first, and later from three shafts. No. 1 shaft, reported to be 95 feet deep, was sunk on a deposit which the magnetometric survey indicates to be of very small extent. No. 2 and No. 3 shafts at the main ore body are reported to have depths of 130 and 100 feet, respectively. All the old workings are now filled with water.

The total shipments from the property between 1880 and 1914 are reported to have been 54,783 long tons. No analyses of the ore shipped are available, but an average sample taken across the ore body by E. Lindeman gave the following analysis:—

	Per cent.
Iron	47.30
Insoluble	30.90
Sulphur	2.21
Phosphorus	0.018

No data as to mining costs and selling price of ore shipped have been furnished. Canada Iron Mines, Limited, estimate that ore can be put on cars for $1.50 per ton. The freight rate to Trenton is 50 cents per ton.

The owners estimate the main ore body to have a length of 600 feet, a width of 30 feet, and a depth of 360 feet, and they estimate the probable tonnage of ore contained in it at 600,000 tons,[1] and the average composition of this ore to be as follows:—

	Per cent.
Iron	51.40
Silica	13.00
Sulphur	1.71
Phosphorus	0.045

This ore they estimate can be concentrated in the ratio of 1.3 to 1, yielding a concentrate which will require roasting or sintering to reduce the sulphur content to a point satisfactory to blast furnace operators.

REFERENCES: E. Lindeman, Mines Branch, Ottawa, Publication No. 184, p. 14.
W. J. McLaughlin for Canada Iron Mines, Limited, Trenton, Ont., 1914.

[1]W. J. McLaughlin

B. OTHER IRON ORE DEPOSITS

1. District of Rainy River

ATIKOKAN AREA

Between Kawene and Atikokan stations on the Canadian National railway outcrops of magnetite and pyrrhotite have been found intermittently along the Atikokan river for a distance of about 16 miles. This iron-bearing area is known as the Atikokan iron range. The range is geographically broken by Sabawe lake into an eastern and a western portion. The eastern portion extends for a distance of a little over 3 miles to Attraction lake, and the western for about 10 miles to a point a little east of Atikokan station.

Numerous mining locations have in the past been taken up on the range, and a considerable amount of prospecting and development work has been done on some of these properties, particularly on location E10 and E11 in the eastern portion of the range. The locations were formerly known as the McKellar property, but are now known as the Atikokan mine.

Eastern Portion of Atikokan Iron Range

From Sabawe lake to Attraction lake the existence of the iron range is indicated by ore outcrops on the ridges and by magnetic attraction in the drift-covered areas. The magnetic belt crosses the following mining locations in order from west to east: E24, E23, E10, E11, E12, E25, and E26. Mining locations E10 and E11 are the only ones of this group on which any extensive development work has been done. They, together with E12, are the property of the Atikokan Iron Company, and are known as the Atikokan mine.

Atikokan Mine (Mining Locations E10 and E11).—See page 155.

Mining Locations E12, E25, and E26.—From the east end of the ore deposits on E11, the ore-bearing belt has been traced eastward over swamp and rock, across mining locations E12, E25, and the greater part of E26. Judging from the magnetometer readings, it has over this stretch a width of from 40 to 75 feet and is continuous, with the exception of two short breaks, for the entire distance.

Very little work has been done on this part of the range so, while outcrops of the decomposed iron-stained rocks of the iron range are of frequent occurrence, actual exposures of magnetite are small and unsatisfactory, and no opportunity is afforded of getting sections through the magnetic belt and ascertaining the width of ore in it. Judging by what can be seen, however, it is probable that any ore bodies will be found to be much smaller than those occurring on E10 and E11 and that the sulphur content will be at least as high as it is in E10 and E11, where sampling of ore lenses cut by exploratory tunnels shows sulphur content to range from 2 to 20 per cent.

Mining Location E23.—From the westerly end of the ridge on mining location E10, where it disappears under the swamp, the ore-bearing belt has been traced westward by magnetometric readings for 2,400 feet, under deep drift all the way. This takes it across about two-thirds the length of E23.

As there are no outcrops, nothing definite is known about either the quantity or quality of the ore here. By referring to the nearest cross-section of the ore-bearing belt available (tunnel A at Atikokan mine), it is seen that the ore there had become highly sulphurous, nearly all the way across the belt. This section showed 7 feet of ore with 18.81 per cent. sulphur, 26 feet with 14.93 per cent. sulphur, 34.5 feet with 6.38 per cent. sulphur, and 8 feet with 1.30 per cent. sulphur.

Western Portion of Atikokan Iron Range

The western portion of the range extends intermittently from Sabawe lake to within about 2 miles of Atikokan station, a distance of about 10 miles. The existence of ore bodies has been proven at different points by tunnels, shafts, and diamond drilling; and magnetometric surveys have demonstrated extensions of ore bodies beneath drift-covered areas. The mining locations in which ore bodies occur (mentioned in order from east to west) are R400, R401, R402, 212X, R403, 139X, 138X, and 111E (near mile post 140 on the Canadian National railway).

Mining Locations R400, R401, and R402.—Mining location R400 is situated about 2 miles west of Sabawe lake and about 1¼ miles northwest of Hematite station on the Canadian National railway.

The claim is 40 chains long and 20 wide, and adjoins claim R401 to the west, which has about the same area. Both claims are bounded by the Atikokan river, R400 on its southwest corner, and R401 along the whole extent of the south side.

The two claims are traversed from east to west by diorite intrusives in which magnetite, pyrrhotite and iron pyrite occur either concentrated into irregular lenses or disseminated in small

amount throughout the rock. Outcrops of diorite carrying some magnetite and sulphides of iron are first met with about 1,100 feet east of the boundary line between claims R400 and R401. From this place the iron-bearing rock may be traced through claim R400 into R401, a distance of 2,200 feet, being especially well exposed near the boundary line between the two claims where the south side of the ridge descends abruptly towards the river. About 100 feet west of this line and at an elevation of about 35 feet above the river a tunnel has been driven into the steep hillside. The length of the tunnel is 74 feet. About 37 feet in from its mouth a vertical shaft, 52 feet deep, has been sunk. The rock formation exposed by the tunnel consists of diorite with irregular pockets of intermixed magnetite and pyrrhotite, or with disseminations of magnetite and pyrrhotite. Average samples were taken from the tunnel by F. Hillé, No. 1 sample representing the ore from 6 to 17 feet, and No. 2 the ore from 17 to 34 feet, footages being reckoned from the entrance.

No. 1	Per cent.	No. 2	Per cent.		Per cent.
Iron	47.48	FeO	31.18		
Silica	17.53	Fe_2O_3	52.37		
Sulphur	4.47	FeS_2	2.26		
Phosphorus	0.04	Al_2O_3	1.30	Iron	62.02
		CaO	1.45	Silica	7.33
		MgO	1.71	Sulphur	1.26
		P_2O_5	0.18	Phosphorus	0.08
		SiO_2	7.33	Titanium	0.10
		TiO_2	0.16		
		H_2O, etc.	1.84		

In addition to this development work, several trenches and cross-cuts have been made at various points along the ridge. The principal open cut on lot R400 is 1,050 feet northeast of the tunnel, exposing the iron-bearing formation across the hill for a distance of 32 feet. The character of the formation is here the same as that seen in the tunnel. An average sample taken along the cut gave the following analysis:—

	Per cent.
Iron	53.10
Silica	11.20
Sulphur	3.87
Phosphorus	0.045

A similar open-cut has been made on the hill side towards the river, about 450 feet west of the tunnel on claim R401. The cut is 45 feet long, 4 feet wide, and 6 feet deep, trending north and south and exposing good magnetite in places, but also sulphides of iron, and rock. An average sample taken along the cut gave the following analysis:—

	Per cent.
Iron	48.80
Silica	16.32
Sulphur	3.84
Phosphorus	0.088

Going westward from this cut the country slopes gently, and no outcrops can be seen for a distance of about 1,000 feet. At this point a narrow ridge with a total length of 2,300 feet, rises above the surrounding muskeg and extends along the river across the westerly part of claim R401 into claim R402 to the west. The greenstone is well exposed on this ridge often exhibiting a rusty appearance owing to the oxidation of iron sulphides with which the rock is heavily charged.

The following analysis represents an average sample taken across the formation at the western end of the ridge. The length of the trench from which the sample was taken is 54 feet.

	Per cent.
Iron	38.56
Silica	41.97
Sulphur	3.50
Phosphorus	0.020

At the close of exploration work by diamond drilling on these locations in 1906, 1907, and 1908, the following estimates as to tonnages of ore proven were made by the engineer in charge (D. B. Rockwell).

On R400 and R401, magnetic iron ore with impregnations of sulphides of iron, 2,055,000 tons of the following average analysis:—

	Per cent.
Iron	52.78
Silica	12.61
Sulphur	3.16
Phosphorus	0.021

On R402, magnetic iron ore and iron sulphide, 264,000 tons of the following average analysis:—

	Per cent.
Iron	52.85
Silica	10.42
Sulphur	10.45
Phosphorus	0.053

References: D. B. Rockwell for R. H. Flaherty, Port Arthur, Ont., 1908.
E. Lindeman, Mines Branch, Summary Report, 1914.

Mining Locations 212X and R403.—Crossing the Atikokan river from location R402, and going westward on claim 212X, no magnetic attraction is noticed for a distance of 1,500 feet, when another magnetic area is reached, which has a total length of 2,900 feet and extends from claim 212X into R403; the only exposure of the iron-bearing formation on claim 212X is in an open-pit near its western boundary line where a considerable amount of pyrrhotite has been exposed. Farther west on claim R403, the country becomes higher and the iron-bearing formation is found along a ridge, rising in places 60 to 70 feet above the river. Numerous trenches and test-pits have been made along this ridge, exposing in most cases pyrrhotite with some magnetite and showing the iron-bearing minerals to occur in irregular lenses throughout the diorite. The width of the area within which these lenses occur may roughly be estimated at 100 feet. An average sample taken from one of the trenches gave the following analysis:—

	Per cent.
Iron	51.00
Silica	2.58
Sulphur	15.28
Phosphorus	0.025

On the conclusion of exploration by trenching and diamond drilling in 1908 and 1909, the engineer in charge (D. B. Rockwell) estimated that there had been proven 2,530,000 tons of iron sulphide (chiefly pyrrhotite) of the following average analysis:—

	Per cent.
Iron	59.80
Silica	3.30
Sulphur	20.40
Phosphorus	0.025

References: D. B. Rockwell for R. H. Flaherty, Port Arthur, Ont., 1909.
E. Lindeman, Mines Branch, Summary Report, 1914.

Mining Locations 139X and 138X.—West of the mineralized area in location R403, there is no indication of any iron ore deposit for a distance of one mile or before claim 139X is reached. This claim lies north of the Atikokan river near mile post 135 on the Canadian National railway. The iron-bearing formation is here exposed in numerous places along a high ridge which extends from claim 139X into the adjoining claim 138X. It consists of the same type of diorite as found on the other claims previously described, with magnetite and pyrrhotite disseminated throughout the rock. In places the pyrrhotite and magnetite are found concentrated in irregular lenses or pockets. The iron and sulphur content of the ore varies considerably. Diamond-drill records kindly furnished the writer by Mr. R. H. Flaherty shows the iron content to range from 62 to 38 per cent., with a variation in sulphur of from 3 to 25 per cent. The phosphorus content is generally low, ranging from 0.006 to 0.045 per cent., while the silica varies from 2 to 16 per cent.

Judging from the magnetometric survey the length of the area within which pyrrhotite and magnetite may be found on these two claims is roughly estimated at 2,600 feet, with a maximum width of about 250 feet.

A few hundred feet farther west, several small detached magnetic areas indicate the presence of pyrrhotite and magnetite. They are, however, of too small an extent to be of economic interest.

After the exploration of these two locations by surface work and diamond drilling in 1908 and 1909, the engineer in charge (D. B. Rockwell) reported that no marketable deposit of ore had been shown up on location 139X, and that on location 138X there had been proven 1,827,000 tons of iron sulphides (chiefly pyrrhotite), of the following average analysis:—

	Per cent.
Iron	55.73
Silica	6.67
Sulphur	20.38
Phosphorus	0.037

References: D. B. Rockwell for R. H. Flaherty, Port Arthur, Ont., 1909.
E. Lindeman, Mines Branch, Summary Report, 1914.

Mining Location 111E.—This property lies about 5 miles west of Hematite station near mile post 140, and about 2.5 miles east of Atikokan station on the Canadian National railway.

The area covered by field work is one mile long and 2,000 feet wide, the greater part of which is occupied by basic igneous rocks of the diorite type. In the southern part, a typical micaceous slate is well exposed along the railway for a distance of about 2,000 feet. The general strike of the slate is N.72°E., with an almost vertical dip.

The chief iron-bearing minerals are iron pyrite with some magnetite. They are found disseminated in small amounts throughout the diorite in several detached areas. These areas generally show a rusty appearance owing to the oxidation of the iron pyrite. The principal occurrence is on a hill about 900 feet northwest of mile post 140. The red-brown gossan can here be traced along the top and flank of the ridge for a distance of 600 feet. At the west end a trench, 50 feet long and 5 feet deep, has been made across the top of the hill, exposing a fine-grained rusty-looking basic rock, with magnetite and iron pyrite disseminated through the mass. An average sample taken along the trench gave the following analysis:—

	Per cent.
Iron	39.50
Silica	20.10
Sulphur	5.37
Phosphorus	0.021

Judging from the magnetometric survey, the total length of this mineralized area is about 830 feet with a maximum width of 110 feet. The magnetic attraction is, however, very irregular within the area, indicating an irregular and pockety distribution of the magnetite in the diorite, and giving little encouragement for finding any ore body of economic importance.

About 800 feet southwest of the area just described, another occurrence of gossan outcrops on the top and along the south side of a small hill. It has a length of 350 feet, with a width of about 50 feet.

Diamond drilling and trenching on this location in 1909 showed lenses of lean magnetite, but no marketable ore.

Across the Atikokan river to the west of the ore occurrence just described, several small areas showing the same rusty-looking rock are found on the steep hill immediately south of the railway tracks. Several trenches and test-pits have been made on this hill, but they failed to reveal any ore body of economic interest.

References: E. Lindeman, Mines Branch, Summary Report, 1914.
A. H. A. Robinson, Mines Branch, Summary Report, 1914.
F. Hillé, Mines Branch, Publication No. 22.
D. B. Rockwell for R. H. Flaherty, Port Arthur, Ont.

HUNTER ISLAND AREA

Banded iron formation exposures occur in a small area close to the international boundary, which comprises the extreme southeasterly portion of the District of Rainy River. Occurrences are reported near Knife, Cypress, This Man and Jasper lakes, the trend of the band being north-northeast. The formation is composed of jasper interbanded with hematite or magnetite, the bands being usually less then one inch in thickness. An exploration of the Hunter Island area is described by A. L. Parsons in the report of the Bureau of Mines, 1916.

References: Geological Survey of Canada, Vol. IV, p. 27A.
Geological Survey of Canada, Vol. V, pp. 63 and 75G.
Reports for R. H. Flaherty, Port Arthur, Ont.

KAIARSKONS LAKE AREA

Kaiarskons lake is located about 10 miles north of the north arm of Rainy lake, and about 35 miles north of Fort Francis.

Deposits of siliceous magnetite, with some higher grade lenses, are reported from this locality. They have been slightly explored but no data are available.

References: A. B. Willmott, Journal Canadian Mining Institute, 1908, p. 116.

RAINY LAKE AREA

Township of Miscampbell

Iron ore discoveries have been reported from *lots 3, 4, and 5, in concessions I and II of Miscampbell township.* A little exploratory work, consisting of test-pitting, stripping, and diamond drilling, has been done.

Rock outcrops in this area are comparatively few, and all show biotite-granite gneiss. The iron showings consist of small, narrow and irregular bands of greyish granular gneiss in which magnetite in small grains is a prominent constituent. The magnetite occurs both disseminated

through the bands, and in narrow streaks. The iron-bearing bands are distinctly friable and crush easily, giving a good separation of magnetite from the gangue minerals. The widest band uncovered has a maximum width of 12 feet.

REFERENCES: Ontario Bureau of Mines, Annual Report, 1912, p. 27.
A. H. A. Robinson, Mines Branch, Summary Report, 1914.
L. L. Bolton for Lake Superior Corporation, Sault Ste. Marie, Ont., 1912.

Township of Watten

Mining Locations, K200, K204, and K205.—The existence on location K200, of two deposits of hematite, one 40 feet wide and one 20 feet wide separated by a "horse" of quartz is reported. A tunnel, intended to be 150 feet long, and designed to cut the ore bodies 100 feet beneath the surface outcrops, was discontinued at 65 feet from the entrance. The last 20 feet was in magnetic ore. The following analyses have been furnished:—

	Hematite per cent.	Magnetite per cent.
Iron	59.16	66.26
Sulphur	0.07	0.067
Phosphorus	0.588	0.018
Manganese	0.81	0.45
Titanium	nil	nil

REFERENCE: Private communication: The Lichen Island Mining Company, Limited, Sarnia, Ont.

Nickel Lake.—On the south side of Nickel lake, the Canadian National railway cuts through a considerable stretch of iron formation, consisting largely of granular silica occasionally banded with magnetite, but more often charged with sulphides, especially pyrrhotite. In places the sulphides become massive, hardly anything else being present. One band of pyrites, 15 feet thick, just at the shore of Nickel lake, may in the future be of importance as a source of sulphur.

On the northeast shore of Nickel lake, opposite to the railway cuttings just mentioned, a banded siliceous rock with much pyrrhotite is exposed on a small island, and a little inland there is a wide belt of granular silica interbanded with magnetite, both with a steep dip as a rule, and a strike about east and west. The banded silica and magnetite are at least 300 feet wide near the shore of the lake and are present in large amounts a quarter of a mile to the east, where the bands are somewhat contorted, but strike on the whole N. 70°W.

Half a mile farther north a third iron range is reported.

None of these iron ranges contain marketable ore, though some parts of them are strongly charged with magnetite.

Somewhat southeast of Nickel lake and south of Grassy Portage bay, along the line between the townships of Watten and Halkirk, magnetite has also been found, but only in small seams accompanied by pyrite.

REFERENCE: A. P. Coleman, Ontario Bureau of Mines, 1902, pp. 134-135.

Lot 6, Concession III.—About half a mile to the southwest of Nickel lake on lot 6, concession III, there is a deposit of magnetite 24 feet wide and 270 feet long with a strike about east and west. It occurs in a slightly schistose greenstone near the contact with a ridge of granite or gneiss. The magnetite is somewhat mixed with green schist fading off into this rock. No analysis of the ore is available.

REFERENCE: A. P. Coleman, Ontario Bureau of Mines, 1902, p. 135.

Mosher and Horne Iron Locations.—On lots 11 and 12, concession III, considerable surface work has been done, the magnetite deposit being traceable for several hundred feet with a width of about 30 feet. Surface samples assay as follows:—

	Per cent.
Iron	49.10
Sulphur	0.14
Phosphorus	0.019

REFERENCES: W. E. H. Carter, Ontario Bureau of Mines, 1902, p. 266.

Lots 3 and 4, Concession V.—On these lots small veins, or segregations of magnetite, have been found in a very siliceous rock.

REFERENCE: A. P. Coleman, Ontario Bureau of Mines, 1902, p. 135.

Township of Halkirk

Bear Pass.—Where the Canadian National railway crosses Bear Pass in Halkirk township, a few small outcrops of granular silica with magnetite occur embedded in rusty gneiss. They do not appear to be of any importance, nor are the locations taken up for iron ore to the west of much promise.

REFERENCE: A. P. Coleman, Ontario Bureau of Mines, 1902, p. 134.

Seine Bay

Many years ago a large number of iron locations were taken up along the north shore of Seine bay, at the northeastern extremity of Rainy lake. The ore is titaniferous magnetite associated with occurrences of a dark hornblende gabbro.

Mining Locations 181P, 182P, and 183P.—In 1911 a little surface work and diamond drilling was done on these locations. An ore-bearing area 300 by 3,200 feet was proven, in which there are numerous narrow lenses of titaniferous magnetite, the maximum proven width of any one ore body being 33 feet. The lenses strike approximately east and west, and stand about in the vertical. The ore is a lustrous titaniferous magnetite, through which is disseminated some easily altered mineral, as chlorite may be detected in nearly all surface specimens. The ore is decidedly friable, the core recovery from diamond drilling having been only 50 per cent. The associated rocks are chlorite schist, green and brown schists, greenstone, and gabbro.

The following are analyses of ore encountered in drilling, the footages sampled varying from 15 feet to 45 feet:—

	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7
	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.
Iron	47.50	45.16	42.71	45.82	36.40	40.44	43.09
Phosphorus	0.012	0.009	0.010	0.080	0.012	0.020	0.010
Titanium	8.09	12.83	11.88	9.42	6.85	11.18	6.08

REFERENCES: A. C. Lawson, Geological Survey of Canada, Memoir No. 40, p. 42.
L. L. Bolton for Lake Superior Corporation, Sault Ste. Marie, Ont., 1911.

Mining Locations, A.L. 25, A.L. 26, and A.L. 27.—Ore bodies occur in a ridge extending in a north-northeasterly direction across the northern portion of claims A.L. 25, 26, and 27. No work has been done to prove the extent of the ore bodies. Four outcrops which were examined were sampled with results as follows:—

	No. 1	No. 2	No. 3	No. 4
	per cent.	per cent.	per cent.	per cent.
Iron	51.34	41.34	47.41	46.81
Silica	7.80	11.20	5.28	6.02
Phosphorus	0.012	0.283	0.007	0.007
Titanium dioxide	11.18	17.36	23.60	20.96

REFERENCE: W. W. Benner for R. H. Flaherty, Port Arthur, Ont., 1910.

STEEP ROCK LAKE AREA

Steep Rock lake lies north of the Canadian National railway in the vicinity of Atikokan station. On the shores of the lake, small blocks of very pure hematite have been found plentifully. This led to many locations being staked for iron and to considerable exploration by diamond drilling. The rocks drilled included hornblende and chlorite schists, traps, cherts, and siliceous bands of considerable width carrying iron pyrites. No bodies of merchantable ore have been located.

REFERENCES: Ontario Bureau of Mines, 1904, Part I, pp. 42-43.
Reports for R. H. Flaherty, Port Arthur, Ont.
Reports for Lake Superior Corporation, Sault Ste. Marie, Ont.

Mining Location 735.—The finding of chunks of good hematite led to the sinking of several test pits and a shaft 30 feet deep. The test pits revealed no ore, and the dump at the shaft shows only low-grade hematite with short and narrow bands of magnetite.

REFERENCE: G. L. Michael for Lake Superior Corporation, Sault Ste. Marie, Ont., 1909.

Mining Claims F.F. 159 to 164, inclusive.—This group of claims lies along the south side of Seine river, about 3 miles below the outlet of Steep Rock lake. The plentiful occurrence of angular "floats" of chert carrying limonite on a ridge stretching through the southerly part of the claim prompted exploration in a ravine immediately to the north. Twelve test pits were dug to ledge, ten of which are reported to have shown cherty iron formation; a shaft 5 by 5 feet was sunk 30 feet, the lower 25 feet of which is in iron formation consisting of light and dark grey chert carrying small pockets of hard brown limonite; and five diamond drill holes were put down, some of which showed ore. A band of iron formation probably extends for a considerable distance through the ravine, but it is evidently of such small extent as to warrant no further exploration.

REFERENCE: L. L. Bolton for Lake Superior Corporation, Sault Ste. Marie, Ont., 1912.

Mining Claims F.F. 46 and 51.—On these claims, located 1½ miles north-northwest of Elizabeth (formerly Steep Rock) siding on the Canadian National railway, there are outcrops of iron formation composed of jasper and white, grey, and black chert, with very thin streaks of hematite in places. No marketable ore was found.

REFERENCE: D. B. Rockwell for R. H. Flaherty, Port Arthur, Ont., 1909.

Mining Locations 857X and 858X (Straw Hat lake).—These locations were partially explored by the Ontario Government diamond drill in 1902 and 1903 for R. H. Flaherty, of Port Arthur. Only siliceous iron formation with pyritic bands was shown by this work. Additional drilling was done in 1909 revealing limonite in chert, associated with pyritic green stone, and chlorite schists. No marketable ore was located.

REFERENCES: Ontario Bureau of Mines, 1904, Part I, pp. 42-43.
D. B. Rockwell for R. H. Flaherty, Port Arthur, Ont., 1909.

TURTLE RIVER AREA

In 1902, outcrops of banded iron formation of large extent were reported north of Mine Centre (on the Canadian National railway) on an expansion of the Turtle river. No additional information is available.

REFERENCE: A. P. Coleman, Ontario Bureau of Mines, 1902, p. 136.

2. District of Kenora

WINNIPEG RIVER AREA

Iron locations are reported to have been taken up north of Kenora, on the east side of the Winnipeg river, between Lake of the Woods and English river. The ore is reported to be magnetite, but no authentic data are available.

REFERENCE: Report of the Ontario Royal Commission, 1890, p. 64.

LAKE ST. JOSEPH AREA

In an area of Keewatin rocks at the west end of Lake St. Joseph, there are several outcrops of iron formation. Magnetic readings indicate that the range extends through Pewabic and Quigly islands for a distance of over 5 miles. No ore of commercial value was seen.

REFERENCE: W. H. Tuckett for R. H. Flaherty, Port Arthur, Ont., 1912.

LAKE MINNITAKI AREA

On the south side of Lake Minnitaki, about 12 miles southwest of Lake Superior junction, are located the *Louis Lac Seul* and the *Helen iron ranges.* The iron formation is composed of alternating bands of siliceous magnetite, jasper, and spotted schist, and lies between walls of green schist. The deposit is of too low a grade to meet present furnace requirements.

REFERENCE: D. B. Rockwell for R. H. Flaherty, Port Arthur, Ont., 1909.

EAGLE LAKE AREA

Claims have been staked for iron in the neighbourhood of *Detour point* and on *Net and North Twin islands.* On Net island, where narrow bodies of ore of fairly good quality are exposed, exploration by stripping, shaft sinking, and diamond drilling has failed to disclose any quantity of ore deserving of consideration. At depth the principal vein was found to be made up of pyrite with small amounts of chalcopyrite.

REFERENCES: A. L. Parsons, Ontario Bureau of Mines, 1912, p. 184.
W. W. Benner for R. H. Flaherty, Port Arthur, Ont., 1910.

DRYDEN AREA

Outcrops of banded iron formation have been found on both sides of the Wabigoon river near *Dryden station* on the Canadian Pacific railway. The iron formation is also fairly well displayed on the railway just east of mile post 216, on lot 23, concession IV, of the Township of Zealand. Here the granular silica, banded with magnetite, is interbedded with grey gneiss or mica schist, the widest belt of silica and magnetite being about 10 feet across. The strike is about N. 50°E., and the dip 80° to the northwest; but the bands are a good deal contorted, and the schists are penetrated by some dikes of granite.

A stretch of drift hides the range for some distance to the east, but it is found again north of *Barclay siding*. Here about three-quarters of a mile north of the railway, at the corner between lots 16 and 17 in the fifth concession and the corresponding lots in the sixth, siliceous rock banded with magnetite is found, sometimes interbedded with schist or gneiss, having a strike of about N. 80°W.

At *Barker's farm* on the west side of Thunder lake, the iron range crops out again as crumpled masses, sometimes very rich in magnetite, but often containing a considerable amount of silica and hornblende. So far no ore of workable quality has been disclosed. The total distance within which outcrops of iron formation have been found, is about 9 miles. The width of the iron formation ranges from 100 to 200 feet. The average iron content of the formation is estimated at about 30 per cent.

REFERENCES: A. P. Coleman, Ontario Bureau of Mines, 1902, p. 136.
A. L. Parsons, Ontario Bureau of Mines, 1911, p. 194.

BENDING LAKE AREA

In the vicinity of *Bending lake*, lying 19 miles southwest of Raleigh station on the Canadian Pacific railway, outcrops of iron formation have been located in a belt with a length of about 10 miles. The general strike of the iron formation is N. 45°W., and the dip is from 45° to 55° to the southwest. The iron formation is composed of silica interbanded with magnetite, hematite, and micaceous schist. The magnetite bands vary in thickness from a fraction of an inch to three feet or more. A little diamond drilling, in addition to surface exploration, has been done.

REFERENCES: Geological Survey of Canada, Summary Report, 1891, p. 29 AA.
J. Walsh, Kenora, Ont., 1914.

The Victoria iron range (located 37 miles north of la Seine station on the Canadian National railway and 3 miles east of the fifth meridian) is probably a part of the Bending Lake range, as the characteristics of the range are about as those enumerated above.

REFERENCE: D. B. Rockwell for R. H. Flaherty, Port Arthur, Ont., 1909.

KEEWATIN LAKE AREA

Keewatin lake lies in the southeastern corner of the District of Kenora, and about 15 miles southwest of English River station on the Canadian Pacific railway. Claims located near this lake by A. McClure, and near *Welsh lake* by Paul Stone, show only greenstone and quartz impregnated with pyrite and chalcopyrite. They are of no value as iron prospects.

REFERENCES: D. B. Rockwell for R. H. Flaherty, Port Arthur, Ont., 1910.
W. W. Benner for R. H. Flaherty, Port Arthur, Ont., 1912.

3. District of Patricia

LAC SEUL AREA

Little Shallow lake lies near the headwaters of the English river, about 90 miles northeast of the town of Kenora, and about 15 miles northeast of Lac Seul. On its shores there outcrop several beds of a dark, fine-grained, stratified rock containing a great amount of magnetite and specular iron ore.

REFERENCE: D. B. Dowling (Exploration, 1893), Ontario Bureau of Mines, 1912, Part II, p. 41.

LAKE ST. JOSEPH AREA

On the Albany river at a point about 35 miles below Lake St. Joseph, and 2½ miles below the mouth of the *Etowamami river*, a zone of fine-grained banded magnetic iron ore with slaty partings occurs in an area of Keewatin rocks.

REFERENCE: Robert Bell (Exploration, 1886), Ontario Bureau of Mines, 1912, Part II, p. 65.

SUTTON MILL LAKES AREA

At *the narrows between the Sutton Mill lakes* there are outcrops of nearly horizontal sandstone beds carrying considerable proportions of magnetite and hematite, which simulate the jaspilites in appearance. The average iron content is probably not in excess of 35 per cent.

Reference: D. B. Dowling (Exploration, 1901), Ontario Bureau of Mines, 1912. Part II, pp. 151-155.

4. District of Thunder Bay

ENGLISH RIVER AREA

Bog iron ore is rather widely distributed around the headwaters of the English river which flows northward from English station located on the Canadian Pacific railway, 115 miles west of Port Arthur. Concentrations of sufficient size to attract attention have been found at the *Little Bear lakes*, about 4 miles east of Quorn station on the Grand Trunk Pacific railway, at *Greer and Yellow lakes*, about 12 miles west of the Little Bear lakes, and near *Niblock station* on the Canadian Pacific railway, about 20 miles south of the Little Bear lakes. The deposits are so shallow that no large tonnage of ore is available, and they are not considered of economic importance.

Reference: E. S. Moore, Ontario Bureau of Mines, 1909, pp. 180-195.

MATAWIN IRON RANGE

This range has a length of 35 to 40 miles extending from Greenwater lake eastward, south of lake Shebandowan to the Kaministikwia river, and roughly paralleling the Canadian National railway. The iron range is not continuous for all this distance but forms a series of detached areas or lenses of various sizes, which generally have an east and west trend and an almost vertical dip. The intervals between the various areas of iron formation vary considerably, and in places have a length of several miles.

The iron formation consists of jasper and other closely related siliceous material, usually interbanded with magnetite, and occasionally with hematite. The range is geographically separable into three areas, the western or Greenwater lake area, the central or Shabaqua area, and the eastern or Conmee area, which will be described in the order mentioned.

Greenwater Lake Area of Matawin Iron Range

Mining Locations B526 to 530, inclusive.—These lie on the east shore of Greenwater lake, and are about 8 miles south of Kashaboiwe station on the Canadian National railway, which is located about 82 miles west of Port Arthur. Iron formation bands extend for considerable distances through these locations, the width of the bands being in some cases as much as 48 feet. The formation is composed of fine-grained magnetite interbanded with schists. The quantity of iron formation on the property is in all probability large, but the average iron content is low.

At *Long Point lake*, east of Greenwater lake, dark green serpentine is found associated with magnetite.

Reference: A. P. Coleman, Ontario Bureau of Mines, 1895, p. 81.

Moissinac Claims.—These claims, six in number, extend northeast from Horseshoe lake, and are about 4 miles east of the locations just described. On them are numerous exposures of banded iron formation, these bands being comparatively narrow and rarely reaching 50 feet in width. The iron mineral is magnetite, and this occurs in bands varying from one-sixteenth to three inches in thickness. In some places, magnetite comprises 50 per cent. of the total volume. A considerable amount of surface exploration has been done without any large ore bodies being uncovered. A sample of freshly broken iron formation gave the following analysis:—

	Per cent.
Iron	26.09
Silica	52.80
Sulphur	0.371
Phosphorus	0.077

Reference: L. L. Bolton for Lake Superior Corporation, Sault Ste. Marie, Ont., 1910.

Shabaqua Area of Matawin Iron Range

The portion of the Matawin iron range which has so far attracted most attention is that in the vicinity of Shabaqua station on the Canadian National railway (about 53 miles west of Port Arthur), where a large number of claims have been staked on both sides of the Matawin and

Shebandowan rivers. One group of mining locations, W211 to 228, inclusive, covers the most promising looking part of the range, an area measuring one mile wide from north to south, and about 7 miles from east to west. The iron range in this area will be described in detail commencing at the east.

Mining Location W211 is the most easterly one on which exploration work has been done. In 1892, a shaft was sunk here on a bed of jasper associated with some bands of high-grade magnetite. The iron formation occurs in chlorite schist and has been traced for a distance of about 495 feet. It has a width of 95 feet at the west and 49 feet at the east end. It consists chiefly of jasper and is considered to be of little economic importance.

Mining Location W212 adjoins W211 to the west. At the southeastern end of this claim, iron formation is exposed by a stripping 66 by 30 feet.

An average sample of the iron formation gave the following analysis:—

	Per cent.
Iron	27.10
Silica	50.10
Sulphur	0.08
Phosphorus	0.16

Mining Location W213 joins the last-mentioned location to the west. As yet no exposure of iron formation has been found on it.

Mining Location W214 is west of W213. In the middle of this location an outcrop of very siliceous iron formation is exposed, 309 feet in length and 213 feet in width.

Mining Location W215 is situated due west of W214. On this claim the iron formation has been traced by dip needle readings for nearly 1,800 feet. A stripping in the middle of the claim shows it to be 73 feet wide at that point. An average sample of the iron formation taken from this place gave the following analysis:—

	Per cent.
Iron	30.6
Silica	47.8
Sulphur	0.04
Phosphorus	0.11

South of this deposit another deposit has been traced by dip needle westward towards the adjoining claim. It has been exposed by a stripping in one place and shows a width of 55 feet.

REFERENCE: F. Hillé, Mines Branch, Ottawa, Publication No. 22.

Mining Location W216 is situated on the south side of the Matawin river where the Shebandowan river flows into it. The Canadian National railway traverses nearly the whole north part of the location.

The iron formation is well exposed on a hill about one-quarter of a mile south of the railway track and about 800 feet west of the eastern boundary of the claim. It consists of a fine-grained bluish-grey siliceous slate through which exceedingly fine crystals of magnetite, hardly visible to the naked eye, are disseminated. The average iron content of the formation is very low. Two samples taken at the east and west ends of the exposure and representing widths of 57 and 35 feet, respectively, gave the following analyses:—

	No. 1 per cent.	No. 2 per cent.
Iron	20.99	20.90
Silica	61.26	63.04

Going westward several other smaller exposures of iron formation can be seen on this claim. The iron-bearing series is, however, of even a leaner character than that previously described, and may be classed more appropriately as ferruginous slate. Sufficient magnetite is present in the rock to enable it to be traced across the claim by magnetic readings, but from an economic point of view the occurrence is of no importance.

Mining Location W217 is situated due west of W216. It is heavily covered with drift, and no outcrops of the iron-bearing series are visible, but by magnetometric readings the band of iron formation can be traced across the whole width of the claim, i.e., about half a mile.

Mining Location W218 is due west of W217 and is one mile long and half a mile wide. The iron formation is prominently exposed near the western boundary line of the claim on a big cliff, rising about 25 feet above the surrounding country and having an elevation of 1,450 feet above sea level. The character of the iron formation is similar to that previously described, though its iron content seems to be somewhat higher as shown by the following analysis representing an average sample taken across an outcrop 47 feet wide near the cliff:—

	Per cent.
Iron	29.49
Silica	52.14

Another sample taken about 500 feet farther east and representing an outcrop 17 feet wide, gave the following analysis:—

	Per cent.
Iron	30.25
Silica	51.25

Judging from the magnetometric readings and a few outcrops, the iron-bearing formation can be traced across the whole width of the claim, reaching its maximum width of 300 feet about 700 feet east of the western boundary line of the claim.

Mining Location W219 adjoin W218 to the west. It is one mile long and half a mile wide and is divided into two parts by the Matawin river. The iron-bearing formation can be traced by magnetic readings from the eastern boundary line of the claim westward to the Matawin river, a distance of 1,200 feet. It is well exposed in a ravine south of the old camps, and even more prominently along two small knolls farther west near the river. The iron formation is leaner than that of the claim previously described. Four samples taken at various points across the formation and representing widths of 47, 75, 52, and 33 feet, respectively, gave the following analyses:—

	No. 1 per cent.	No. 2 per cent.	No. 3 per cent.	No. 4 per cent.
Iron	13.38	24.28	17.31	17.81
Silica	70.03	58.78	66.70	65.05

For a distance of about 1,700 feet west of the Matawin river the magnetometric survey gives no indication of any continuous iron formation, and a few very small scattered magnetic areas are all that can be found on this part of the claim.

Mining Locations W220, W221, and W222.—About 350 feet west of the boundary line between W219 and W220 the magnetic attraction comes in again, and from that point westward the iron formation can be traced by outcrops and magnetic readings, with the exception of one or two small intervals through claims W220, W221, and W222, a distance of 7,000 feet. Judging from the magnetometric survey the width of the iron-bearing formation on claim W220 may be roughly estimated at 50 to 200 feet. It increases, however, considerably on claim W221 and reaches a width of over 1,000 feet near the boundary line between W221 and W222. Farther west on W222, the iron formation decreases again in width, being 100 to 400 feet wide.

On claims W221 and W222 the iron formation consists chiefly of a fine-grained siliceous hematite interbanded with siliceous material, black and red chert. Judging from the magnetic character of the formation, magnetite is also present. Four samples taken across the exposed formation at various points gave the following analyses:—

	No. 1 per cent.	No. 2 per cent.	No. 3 per cent.	No. 4 per cent.
Iron	25.07	29.35	30.89	27.86
Silica	54.20	48.76	46.34	49.44

The widths of the exposures from which the samples were taken were 100, 35, 36, and 47 feet, respectively. Samples Nos. 1 and 2 are from claim W221, 3 and 4 from W222.

From what has been said in regard to the extent of the iron formation on locations W216 to 222, inclusive, it is evident that a large quantity of low-grade ore is available, all of which, however, requires fine crushing and concentration with subsequent briquetting or nodulizing before it can be made marketable. To carry on such an operation profitably at the present time does not seem feasible, owing to the low iron content of the ore and the extreme fineness to which the grinding would have to be carried before a satisfactory separation could be obtained. The iron formation of the western claims W221 and W222 offers also another objectionable feature for magnetic separation on account of the iron-bearing mineral being present there chiefly in the form of hematite.

Reference: E. Lindeman, Mines Branch, Summary Report, 1914.

About half a mile north of the Matawin river there is another deposit on *mining locations R476 and R484*. It commences at the eastern part of R476 and extends through this location into the adjoining one, a distance of about 3,000 feet. Magnetic dip needle readings show a very high average for over 132 feet across this deposit. It differs somewhat in character from those previously described. Here the magnetite is not so intimately mixed with the silica, but forms separate bands of various sizes which are interbanded with jasper.

An average sample of this ore gave:—

	Per cent.
Iron	51.48
Silica	25.95
Phosphorus	0.25
Sulphur	0.04

About nine chains north of this deposit the dip needle indicates the presence of another ore body, the extent of which has not been ascertained.

Reference: F. Hillé, Mines Branch, Ottawa, Publication No. 22.

On *Mining Locations R412, 479, 480, 483, 490, 499, 509, and 511*, there occur outcrops of iron formation composed of jasper or chert interbanded with magnetite and hematite. The deposits do not appear attractive enough to warrant exploration.

Reference: D. B. Rockwell for R. H. Flaherty, Port Arthur, Ont., 1907.

On *Mining Locations W232, 233, 234, 236, 237, 238, 239, 241, 242, 243, 244, and H.P. 673*, there are belts of iron formation composed of banded jasper, magnetite, hematite, and iron-bearing slates.

Reference: R. H. Flaherty, Port Arthur, Ont., 1909.

On *Claim T.B.910* and some others near it, there are outcrops of iron formation composed of jasper or granular silica interbanded with magnetite. The magnetite appears to be of good quality and occurs in bands clearly separated from the gangue, and frequently with a thickness of from two to three inches. The ease with which a good magnetic concentrate could be secured, and the possibility of finding large tonnage, has made this appear as an interesting concentrating proposition.

References: G. L. Michael for Lake Superior Corporation, Sault Ste. Marie, Ont., 1909.
R. H. Flaherty, Port Arthur, Ont., 1909.
W. W. Benner for R. H. Flaherty, Port Arthur, Ont., 1910.
W. H. Tuckett for R. H. Flaherty, Port Arthur, Ont., 1910.

On *Location R492* the iron formation appears to carry only 20 to 25 per cent. magnetite, and the magnetite is lean-looking and occurs in bands less than two inches thick.

Reference: D. B. Rockwell for R. H. Flaherty, Port Arthur, Ont., 1910.

Conmee Area of the Matawin Iron Range

Scattered through the township of Conmee from concessions I to VIII, in the unsurveyed territory to the west, and in the townships of Ware and Oliver to the east, there are numerous outcrops of iron formation, the whole group being regarded as the eastern end of the Matawin iron range.

The siliceous ingredient of the iron formation is nearly everywhere jasper, and with this is interbanded both hematite and magnetite; occasionally, as in the vicinity of Mokom n station (32 miles west of Port Arthur) pyrite is the most noticeable constituent of the iron formation. The hematite and magnetite bands vary in thickness usually from a mere film to two or three inches; but at some occurrences a thickness in excess of 12 inches is reported, as in *lot 4, concession III, Conmee township*, and on *Kaministikwia mountain in location R333* in Ware township, the latter of which has attracted some interest as a possible concentrating proposition.

While few outcrops of iron formation in this area seem to have been left unstaked, the showings seem not to have been attractive enough to lead to extensive exploration. A few of the properties which have attracted attention (in addition to the two mentioned above) are *mining locations R393, R394, and R411*, near Mokomon, showing lean interbanded jasper and magnetite; the *Muirhead claims*, just west of the above, where there is a band of iron formation with a width of 450 feet, an average sample from across which assayed 34.10 per cent. in iron and 49.00 per cent. in silica; the *Montgomery and Strathy claims* in concessions I and II; *mining locations B.J. 128, 129, and 130*, and the *Pumpelly-Smyth holdings.*

References: A. P. Coleman, Ontario Bureau of Mines, 1902, p. 129-130.
Private reports for R. H. Flaherty, Port Arthur, Ont.
Private reports for Lake Superior Corporation, Sault Ste. Marie, Ont.

GUNFLINT-WHITEFISH LAKE AREA

Under the above title is included the territory adjacent to the North Lake branch of the Canadian National railway (formerly the Port Arthur, Duluth and Western railway) from Gunflint lake on the international boundary easterly approximately 35 miles to Whitefish lake.

In this area numerous locations have been taken up for iron ore. The ore occurring on most of these locations consists of thin layers of magnetite or hematite, interbanded with cherts of the Animikie series, but as yet no deposit of sufficient size to warrant exploitation has been found.

Reference: E. Lindeman, Mines Branch, Summary Report, 1908, p. 52.

PORT ARTHUR AREA

In the township of McGregor, about 7 miles northeast of the city of Port Arthur, on section 16, concession C, and on mining location 242 in the same locality, a little exploratory work has been done on beds of magnetite associated with the sideritic cherts of the flat-lying Animikie series. The ore is a high-grade magnetite, comparatively free from deleterious constituents, but as yet no beds of sufficient thickness to yield attractive tonnage have been located.

Reference: L. L. Bolton for Lake Superior Corporation, Sault Ste. Marie, Ont., 1912.

LOON LAKE AREA

The Loon lake iron-bearing area lies about 26 miles east of Port Arthur, and is traversed by the main line of the Canadian Pacific railway. Four definite horizons are present in the iron-bearing formation:—

1. The upper black slate.
2. An upper iron-bearing member.
3. An interbedded black slate.
4. A lower iron-bearing member.

The two iron-bearing horizons are themselves quite different in character. The original rock of the upper horizon is a rather thin-bedded, cherty, dark grey to very light-coloured iron carbonate. A common phase of this horizon is a banded rock composed of alternating layers of iron oxide or partially altered carbonate and light, or dark-coloured, or red iron-stained chert. All stages of gradation can, however, be observed from the original unaltered cherty carbonate rock, through the ferruginous cherts and slates, to iron ore. At the base the upper iron-bearing formation grades into the underlying slate.

The lower iron-bearing horizon can, except where extremely altered, be readily distinguished from the upper by the constant presence in it of small granules which are entirely absent from the upper horizon. Chemically these granules are essentially hydrous ferrous silicate. Very frequently, however, the matrix surrounding the granules is largely carbonate material which varies from exceedingly fine to very coarse grained. Associated with the granule-bearing rock of the lower horizon and, in part at least, secondary to it, are phases which show varying degrees of alteration to or replacement by iron oxide. Of the rocks of the formation which contain a high enough percentage of iron to be classed as ore, two phases are characteristic. One is a fine-grained red and blue hematite of medium hardness. The other is one whose texture is that of a medium to coarse grained carbonate rock, but with the red colour of hematite. That in this latter variety iron carbonate and iron oxide are both present is shown by chemical analysis of certain samples which give higher percentages of iron than is contained in iron carbonate.

The localities in which the greatest concentration of iron has as yet been proven, are included in the area extending 4 miles west, 2 miles south, and 1 mile east of Loon lake station. The properties on which exploratory work has been carried on are known as the *Flaherty-Knobel, Marks-Wiley*, and *McConnell properties.* In these areas numerous diamond-drill holes have been put down and a considerable amount of trenching and test-pitting has been done in search for iron ore. The result of the work thus far done shows that over the greater part of the area the lower iron horizon has been extensively altered to iron oxide, but that, associated with the layers showing the greatest concentration, a considerable amount of lean siliceous material is present, either as lenses in the hematite or as layers interbedded with it. Thus the average sample of any considerable vertical section is of low grade. The following analyses are representative of the grade of ore occurring here:—

	No. 1 per cent.	No. 2 per cent.	No. 3 per cent.	No. 4 per cent.
Iron	26.51	31.24	40.20	19.68
Silica	34.78	30.86	44.76	61.04
Sulphur	0.06	0.06	0.04	0.13
Phosphorus	0.04	0.08	0.06	0.06

A diamond-drill hole penetrating the ore-bearing strata in reaching a depth of 45 feet, cut two bands of ore with thicknesses of 6½ feet and 1¾ feet, respectively, three bands of lean ore with thicknesses varying from 3 to 5 feet, and three bands of ferruginous chert with thicknesses varying from 6 inches to 3 feet. This is typical of the results secured from many drill holes.

These properties have been examined by several engineers, all of whom apparently are agreed that the mining of ore from them would be essentially a sorting proposition, with the chances of economic operation decidedly poor.

REFERENCES: W. N. Smith, Ontario Bureau of Mines, 1905, p. 254.
L. P. Silver, Ontario Bureau of Mines, 1906, p. 156.
R. W. Seelye for Lake Superior Corporation, Sault Ste. Marie, Ont., 1906.
Private reports for T. J. Drummond, Montreal, Que.

Dominion Bessemer Ore Company Property.—About 4 miles to the southwest of the above described area lies mining section No. 5, in the Township of McGregor, which was operated in 1909 by the Dominion Bessemer Ore Company and from which two cargoes of ore were shipped before the close of navigation. An ore-loading dock was built, also a tramway from the dock to the ore body about one mile inland. Operations ceased at the end of the year and were not resumed.

The ore on this property occurs in two varieties: as hard, greyish, fine-grained hematite; and as friable, brown oxides of iron. The ore-beds are associated with quartzose and sideritic rocks, with a prevailing dip to the southeast of about 50°; they attain in places a thickness of 6 feet, but a thickness of more than 3 feet is not common. Frequently the ore beds thin rapidly. In

the better ore beds high-grade ore occurs in segregations with the result that where a whole bed is mined the average iron content of the ore, after cobbing in the quarry, is likely to be below present furnace requirements.

Average analysis of stock-pile samples taken while mining operations were in progress, are reported as follows:—

	No. 1 grade per cent.	No. 2 grade per cent.
Iron	44.30	37.60
Silica	22.60	23.00
Sulphur	0.015	0.275
Phosphorus	0.015	0.024
Manganese	1.50	4.00

The improbability of finding large tonnage and the reported inferior grade of shipments made from mining operations, have deterred further exploitation.

REFERENCES: L. L. Bolton for Lake Superior Corporation, Sault Ste. Marie, Ont., 1909.
R. W. Seelye for Lake Superior Corporation, Sault Ste. Marie, Ont., 1910.
Ontario Bureau of Mines, Vol. XIX, 1909, p. 81.

DOG LAKE AREA

About 25 miles northeast of Dog lake, and about 50 miles due north of Port Arthur lies Little Pine lake. Immediately to the west of *Little Pine lake* a group of 20 claims (T.B. 2020 to 2039) have been staked for iron and about 4 miles to the northwest of the lake another group of 27 claims (T.B. 1731 to 1757) have been taken up for iron. From the best information obtainable it appears that the iron showings in this locality consist of bands of iron formation composed of interbanded jasper, magnetite, and hematite, similar to that occurring in many other parts of Thunder Bay district.

REFERENCE: B. Stuart McKenzie, Winnipeg, Man., 1914.

BLACK STURGEON AREA

A number of iron locations were taken up years ago southwest of Lake Nipigon on the *southeast side of Black Sturgeon lake*, to the *east of Black Sturgeon river*, to the *east of Nonwatin lake*, and to the *west of Fraser lake*. Slight seams of hematite associated with grey schist and jasper can be seen on some of these locations, but as yet no ore body of economic importance has been found.

REFERENCE: A. P. Coleman, Ontario Bureau of Mines, 1909, pp. 170-172.

LAKE SAVANT IRON RANGE

Lake Savant is about 20 miles northwest of Bucke station on the National Transcontinental railway. West of this lake banded iron formation has a wide distribution. Beginning on the west shore of the lake it extends more or less continuously westward for about 25 miles, reaching beyond the southern end of Cliff lake. South of the eastern portion of *Lake Kashaweogama* (10 miles west of Savant lake), the range becomes more concentrated, and the most important portion of it lies in this vicinity. The range is here about 1 mile wide, with a band about a quarter of a mile wide, fairly free from country rock. South of the main band there are a number of parallel narrow bands of no economic interest.

Part of the western portion of the range is composed almost entirely of banded quartz and actinolite, but generally the iron formation consists of banded red jasper and magnetite and quartz in the form of interlocking crystals developed by the crystallization of chert. The bands in the jasper vary in width from microscopic size to a quarter of an inch or even an inch in width. This jasper is again interbanded with wide and narrow bands of greywacké, hornblende schist, and a grey, fine-grained gneiss. By far the most common rock occurring with the red jasper and magnetite is greywacké, and the bands of jasper and greywacké vary greatly in width. In places there is as much as 50 feet of almost pure red jasper and magnetite, while in others these minerals occur as bands only an inch or two wide in large masses of schist or greywacké.

Two picked specimens of iron formation gave the following analyses:—

	No. 1 per cent.	No. 2 per cent.
Iron	33.36	43.82
Silica	50.20	39.00

A good deal of test-pitting and stripping has been done, and one or two shafts have been sunk 15 or 20 feet, but there has been no drilling, and so far nothing which can be regarded as "pay ore" has been located. The greater portion of the iron formation, even where free from schist, does not carry more than from 30 to 35 per cent. of iron.

The only portion of the range which may be of some economic interest is the widest belt south of Lake Kashaweogama. The length of this belt is about 3 miles with a maximum width of one-quarter of a mile.

REFERENCES: E. S. Moore, Ontario Bureau of Mines, 1910, pp. 186-187.
R. H. Flaherty, Port Arthur, Ont., 1910.

ROUND LAKE AREA (North of Lake Nipigon)

Round lake is an expansion of the Pikitigushi river and lies about 27 miles up the stream and directly north of Windigo bay on Lake Nipigon. About one-third of a mile north of Round lake, some narrow bands of lean iron formation occur in a chloritic or grey gneissic schist.

The length of the range is about one mile, and its width is very indefinite. It shows only in a few places where it outcrops through drift which is very heavy in this region. Bands of magnetite, hematite, and silica, from 8 inches to as many feet in width, occur, but they gradually grade into a fine-grained grey gneiss, or into schist containing much silica and chlorite and in some cases stained with oxidized pyrite. The range is considered to be of little economic importance.

A narrow band of iron formation exposed on *Caribou lake*, 16 miles to the northwest, is possibly a continuation of the Round Lake band.

At *Haystack mountain* close to the National Transcontinental railway, and about 10 miles southeast of Round lake, a number of claims have been staked for iron. Investigation showed that the area included in this staking is underlain exclusively by Keweenawan diabase, and that the iron ore present is ilmenite or titaniferous magnetite, occurring in small segregations throughout the diabase, a mode of occurrence giving no promise of tonnage.

REFERENCE: E. S. Moore, Ontario Bureau of Mines, 1909, pp. 158-162.

ONAMAN IRON RANGES

The Onaman iron ranges lie northeast of Lake Nipigon and surround the head waters of the *Red Paint river*. They extend nearly east and west and are about 2 miles apart. The *Northern range*, beginning below *Holliday lake*, extends across the height of land and along Johnson creek, a distance of almost 10 miles. It is traversed by the National Transcontinental railway. The range is not represented by continuous outcrops, the gaps being of considerable extent. The outcrops are, however, sufficiently close together and the local magnetic attraction, where outcrops do not occur on account of the thick coating of drift, is sufficiently strong to warrant one in regarding this as a continuous band. The width of the range varies greatly. At the western end the range is represented by a few feet of very lean iron formation, but near the *Maple Leaf claims* it widens to nearly half a mile. At this point the area is not, however, occupied by continuous iron formation, but only by narrow outcrops appearing in green schist, tuff, or rhyolite. Where the range crosses the *Height of Land claims* the formation is continuous over a width of 150 yards, but contains a good deal of greywacké and slate; some rhyolite and green schist have been folded into it. The outcrop at the divide disappears under the drift and reappears again on the *Winter Camp claims*, 2 miles to the east, where the formation occurs as narrow outcrops on either side of a mass of greenstone which has been faulted into it. The formation is again hidden under the drift, and 3 miles to the east reappears as a considerable outcrop in the vicinity of the *Miller claims*. Although the range here is broken up by the older rocks near the surface and the formation is hidden from view by the drift which covers portions of this area to a depth of 100 feet or more, sufficient outcrops occur to show that the range can be traced over an area of 2 miles long by 1¼ miles wide. The formation here is, on the whole, pretty lean, there being much slate and schist with the jasper.

Exploratory work on some of the most promising-looking claims on the northern range was performed in 1906 and 1907 for R. H. Flaherty. The following information as to results of this exploration have been furnished.

On the *Height of Land claims* an average sample of an outcrop 2,600 feet long, with a width in one place of 305 feet, ran as follows:—

	Per cent.
Iron	40.49
Phosphorus	0.065

A diamond-drill hole, 254 feet deep, on the Winter Camp claims cut ferruginous schist, and jasper carrying magnetic ore, and a surface outcrop 30 feet wide furnished a sample assaying as follows:—

	Per cent.
Iron	37.92
Phosphorus	0.042

On the *Miller claims* a diamond-drill hole, 143 feet deep, cut ferruginous schist, banded jasper, and magnetite and greenstone. A stripping 50 by 650 feet gave a sample of the following analysis:—

	Per cent.
Iron	43.48
Silica	35.90
Sulphur	Trace
Phosphorus	0.045

The *Northern range* contains a large amount of banded jasper, but scarcely any sign of concentration of iron ores has been found.

The *Southern range* is somewhat more continuous and compact than the Northern. The most westerly outcrop lies along the south side of *Castor lake* where a very narrow band of jasper occurs. There is then a break where drift extends for a mile between this small outcrop and the main portion of the range. It is probable that the formation underlies the drift. The main portion of the range is represented by almost continuous outcrops for a distance of 2 miles, with a maximum width of 700 feet. This range, like the northern one, also contains a good deal of foreign rock in its widest areas. At the east end of the southern range the iron format'on runs under drift, but local deflections of the compass in a large swamp and the occurrence of a very small outcrop of iron formation a mile and a quarter east of the main range, show that the range is continuous for at least a mile and a half under the swamp.

On the Southern range there are wider and longer bands of magnetite than on the Northern range. A sample of one of the better looking bands a few inches wide and several rods long, gave the following analysis:—

	Per cent.
Iron	50.82
Silica	26.85

One of the richest looking outcrops (with a width of 15 feet) was sampled with the following results:—

	Per cent.
Iron	55.79
Silica	37.10

There are many bands of banded jasper and magnetite a few feet wide; a sample from one of these gave the following analysis:—

	Per cent.
Iron	38.83
Silica	50.00

The iron formation of the Onaman ranges includes ferruginous cherts, slates, phyllites, greywackés, actinolite-magnetite-schists, and jaspers. The relations between the rocks of this formation are such that a band of jasper half an inch in width may occur between bands of slate and greywacké 20 feet in width, while on the other hand almost clear jasper bands may reach a maximum of nearly 50 feet. Some of the narrow bands of ferruginous cherts may contain a large percentage of iron, as for example, one band a few inches wide from the southern range which was analyzed and found to contain 50 per cent. of metallic iron and 23 per cent. of silica; but from information given above, it is seen that neither range has been shown to contain ore which can be worked under present conditions.

References: E. S. Moore, Ontario Bureau of Mines, 1909, pp. 196-253.
R. H. Flaherty, Port Arthur, Ont., 1908.

IRON RANGES EAST OF LAKE NIPIGON

East of Lake Nipigon in the vicinity of *Poplar Lodge*, an abandoned Hudson Bay post, there are three iron ranges known locally as the Northern, Central, and Southern ranges. A few miles east of these and a little to the north, there are additional outcrops of iron formation near Windegokan, Still, and Watson lakes. This territory is now easily accessible by the main line of the Canadian National railway which lies not more than 3 miles to the south of the iron ranges. The distance to Nipigon village on Lake Superior is between 60 and 70 miles.

The *Northern range* has a length of about a mile and a quarter, running northeasterly through locations A.L. 408, 407, 406, 405, 404, 403, 402, near the north bank of Sturgeon river, 2 or 3 miles from its mouth. It is seldom more than 50 feet wide, but reaches a width of 240 feet, with intermixed slaty rock at one spot on A.L. 403. In general the banded silica lies just to the southeast of a ridge of greenstone, under which it dips at an angle of 35 to 60 degrees. On the opposite side the iron formation generally runs under old lake deposits towards the river bank.

Both magnetite and hematite occur, though the latter shows red only when powdered. The silica bands are generally cherty or quartzitic, with occasional strips of dull jasper. On the whole the range is too narrow and lean from the admixture of silica and slate to be very promising.

The *Central range* is 3 miles south of the Northern and is first seen a mile and a half inland from Poplar Lodge. This part of the region is mostly covered with sand plains and swamp, so

that solid rock does not crop out very frequently and then only as low, rounded surfaces, making it difficult to prospect without doing much stripping. A considerable amount of work has been done in this way, and three diamond-drill holes have been sunk on the most important outcrop, but undoubtedly much of the range still remains covered. The known outcrops are in four localities: (1) A.L. 414, (2) at the north end of A.L. 413 and 412, (3) in A.L. 416 and adjacent portions of A.L. 413 and H.F. 1, and (4) in H.F. 5. The third area is the most attractive and has been most thoroughly prospected. It shows a wide-spread series of bands of iron formation over a length from east to west of half a mile and a breadth of a quarter of a mile. Including all four outcrops the range has a length of nearly 3 miles, with a breadth of about three-quarters of a mile where widest; but these limits include much drift-covered surface and barren rock, and the most easterly outcrop is separated from the others by a mile and a half in which no iron formation has been found.

The ore is entirely hematite, and the associated silica is jasper, often bright red. In the areas mapped as iron range more than one-half consists of grey and green schist in which fragments and long strips of the iron formation are imbedded. In general the jaspery strips tend to run out into schists towards the east and west. A narrow belt of Huronian conglomerate runs parallel to several of the outcrops and is occasionally repeated several times, as in location A.L. 414. This seems to indicate a number of small parallel folds of the structure, so that the great width of this range is probably due to repetition. In one place on the boundary between A.L. 413 and 416, a diamond-drill hole showed jasper and ore 414 feet below the surface, so that the synclines are not shallow.

In general it may be said that in the iron formation there is a considerable amount of lean ore, generally in narrow bands and lenses separated by several feet of jasper and schist.

Three samples of ore taken by Prof. Coleman gave the following analyses:—

	No. 1 per cent.	No. 2 per cent.	No. 3 per cent.
Metallic iron	44.2	37.4	40.0

A specimen of hard, blue hematite from a surface lens is reported to have run 64.42 per cent. in iron. This was probably a carefully selected specimen, since the average iron content of 33½ feet of ore encountered in drilling was estimated by the late A. B. Willmott to run between 40 and 50 per cent.

The *Southern range* has a length of 7 miles, including interruptions of drift and barren rock, and a maximum width of 500 feet, though the average width is not more than 50 feet. It is separated from the nearest point of the central range by three-quarters of a mile of greenstone and schist rising as a ridge. The Southern range contains a good deal of magnetite, as well as hematite and some jasper. It resembles the Northern range, though much more extensive and also richer in iron. The associated rocks are slate and grey and green schists, and the range fades out laterally into the other rocks. The arrangement is unsymmetrical, the richest and most magnetic ore generally occurring on the north side of the range, while leaner bands are interbedded with slate or schist to the south. The general direction of the range is north of east, following the usual strike of the region; and the dip like that of the Central range, is high, from 60 degrees to vertical.

Five samples of ore from the Southern range gave the following analyses:—

	No. 1 per cent.	No. 2 per cent.	No. 3 per cent.	No. 4 per cent.	No. 5 per cent.
Metallic iron	38.06	30.06	37.19	37.79	34.02
Silica	40.6	.....	.....	.....	.....
Sulphur	Trace	.....	.....	.....	.....
Phosphorus	Trace	.....	.....	.....	.....
Titanium	None	.....	.....	.....	.....

No. 1 was a sample of the best looking ore obtainable; No. 2 was an average sample of formation over a width of 82 feet; and Nos. 3, 4, and 5 were average samples excluding the leaner part of the outcrop.

REFERENCES: A. P. Coleman, Ontario Bureau of Mines, 1907, pp. 115-128.
A. P. Coleman, Ontario Bureau of Mines, 1908, pp. 146-147.

Lying in mining locations H.F. 13, 12, and 10, just west of *Windegokan lake,* there is a mass of iron range of considerable proportions. It is composed of grey slate and jasper, interbanded with hematite. Two samples of the richest looking part of the iron formation show only 35.75 and 36.56 per cent. of iron, respectively. Much of the mass lies under swamp and drift, and although the drift has been partly removed by trenching, it is impossible to say what lies under the swamp. Nothing was seen to justify the assumption that a large ore body exists. There is much schist in some of the range, the dip is about 90 degrees, and there seem to be no particular geological conditions to cause a concentration of ore at this place. This outcrop becomes greatly mixed with schist before running into the eruptive sheet to the west, and also at the east end before disappearing under the drift. Just south of this outcrop and in location H.F. 11, is a small mass of jasper and banded magnetite.

In mining location B.T.O. 1 on the south shore of *Still lake*, there is an occurrence of iron formation of considerable size. A large portion of this is excluded from view by drift and swamp, but it evidently extends from Still lake to White Fish lake, a distance of about half a mile. Although at either end the range has a width of not more than about 15 feet, it widens out in the centre to about 450 feet. Towards the east end it dips under the water of Still lake.

The iron formation is composed of silica, with a little hematite, and with it is intermixed much schist. The best sample taken had an iron content of 36.86 per cent., which is much too low for a merchantable iron ore, and there is no indication of any secondary concentration.

About 1½ miles south of Still lake, a band of iron formation outcrops at the northeast end of *Watson lake.* This extends easterly through locations H.F. 32, 35, 39, and 40, a distance of about 2 miles. Its greatest width is about 100 feet. The formation consists of jasper and magnetite, and it is bounded on the north and south by slaty green schist. The richest specimen of magnetite collected from it ran 48.9 per cent. in iron.

For 6 or 7 miles farther eastward unimportant outcrops of iron formation occur at widely separated intervals, the chief of which are those in locations H.F. 37 and 38 near *Lake Nora,* those in locations H.F. 45 and 46 southeast of *Lake Pasha,* and those to the north of *Lake Nissiamkeekan.* Still farther to the east a few claims have been staked near the headwaters of the *Black river* on showings of iron formation (not more than 6 feet wide) composed of banded sugary silica with a little magnetite.

REFERENCES: E. S. Moore, Ontario Bureau of Mines, 1907, pp. 144-145.
A. P. Coleman, Ontario Bureau of Mines, 1908, pp. 148-154.

LITTLE LONG LAKE AREA

Little Long lake lies about 55 miles north of Jackfish station on the Canadian Pacific railway, and about the same distance east of Lake Nipigon. It is now easily reached by the Canadian National railway which skirts its northern shore, the distance to Nipigon village on Lake Superior being about 115 miles.

The first suggestion of iron formation is found on the south side of the western end of the lake in location A.L. 439, where a few thin seams of banded grey and black material of very low grade occur in a green schist. The largest outcrop of iron formation is at the east end of a large island in *mining location A.L. 431* where stripping discloses a width of 24 yards of iron formation intermixed with schists. Another stripping a short distance west shows 40 yards of surface made up of very lean iron formation without schist and containing some dull red jasper. The chief iron mineral here is hematite. The greatest width of the banded iron formation found on the island is 130 yards, and the total length of the outcrops is a little over a quarter of a mile. West of the lake several locations have been taken up. Several bands of iron formation, mostly very lean, have been found on these claims, and fairly strong local magnetic attraction is noted in several places.

REFERENCE: A. P. Coleman, Ontario Bureau of Mines, 1909, pp. 146-148.

JACKFISH AREA

About 1¼ miles north of Jackfish station and close to the Canadian Pacific railway track are located the workings on location A.L. 383 of the Argenteuil Mining Company. The development undertaken between 1900 and 1903 consisted of two shallow shafts and a tunnel. Operations centred on a faulted zone in hornblende granite, where the crushed rock is cemented by lean, reddish iron oxides. The property has absolutely no value as an iron prospect.

REFERENCE: L. L. Bolton for the Lake Superior Corporation, Sault Ste. Marie, Ont., 1912.

On the *Slate islands,* 8 miles south of Jackfish, there are small exposures of banded jasper and chert.

REFERENCE: A. P. Coleman, Ontario Bureau of Mines, 1902, p. 137.

LITTLE PIC RIVER AREA

On the north shore of Lake Superior near the mouth of the Little Pic river, two locations were taken up for iron many decades ago. It now appears that what attracted attention was the occurrence of a rock (probably hornblende syenite) in which magnetite was present, either disseminated in small grains or segregated in small pockets.

REFERENCES: Peter McKellar, Toronto, Ont., 1874.
Chas. Robb, Montreal, Que.
J. Weatherly, 1873.
T. W. Herrick, Port Arthur, Ont.

WESTERN MICHIPICOTEN AREA

The extreme westerly development of the Michipicoten iron ranges lies in the south-easterly corner of the District of Thunder Bay, and in this locality there are two iron-bearing horizons several miles long, and several occurrences of less interest.

One of these iron-bearing horizons lies just south of the East Branch of the *Pukaskwa river*, and extends from the township of Homer to David lakes, a distance of about 8 miles. All the area has been staked as iron claims, the holdings being known as the *Big Dave, Knapp*, and *Goetz-Conners* properties.

Through the Big Dave and Knapp properties there extend two iron-bearing horizons about 3 miles in length, with a uniform northerly dip of 30 to 40 degrees. The total thickness of these horizons may be 200 feet or more, but the bands of iron formation rarely exceed a thickness of 25 feet, being separated by schist, volcanic breccia, or porphyrite.

The iron formation is composed of alternating bands of grey and white chert and granular silica, and greyish lean magnetite and good magnetite. The magnetite is usually siliceous and the bands are not clean cut; instead they usually blend into the purely siliceous bands. Ordinarily there are four or more bands to the inch. The banding is not always conspicuous as the contrast in colour between greyish chert and lean magnetite is not great. The iron content of average samples of iron formation will be always less than 35 per cent.

From the best information obtainable it seems that the iron formation on the *Goetz-Conners* claims is essentially the same as to mode of occurrence and composition as that on the Big Dave and Knapp properties.

About 4 miles southeast of David lakes the westerly end of another iron-bearing horizon is picked up at Maple lake. This extends brokenly eastward from *Maple lake* to *Cameron lake*, a distance of about 8 miles. The iron formation consists of banded cherts in narrow parallel bands.

Minor occurrences are reported at the mouth of the *Julia river* near Pukaskwa Harbour and elsewhere in the Township of Homer, at *McDougall lake* 8 miles north of the Knapp claims, and near the mouth of *Eagle river*, 6 miles southeast of Cameron lake.

About 25 miles northeast of the Big Dave and Knapp properties near the headwaters of the East Branch of the Pukaskwa river, there is an outcrop of iron range west of Iron lake, which has attracted a good deal of interest, but only the lean westerly end of the range between *Bole and Abbie lakes* lies in the District of Thunder Bay.

REFERENCES: J. M. Bell, Ontario Bureau of Mines, 1905, pp. 313-317.
W. W. Benner for R. H. Flaherty, Port Arthur, Ont., 1910.
L. L. Bolton for Lake Superior Corporation, Sault Ste. Marie, Ont., 1911.
James Conners, Seattle, Wash., 1915.

5. District of Algoma

MICHIPICOTEN AREA

Lying mostly within 25 to 30 miles of the port of Michipicoten Harbour on Lake Superior, is an area with no fixed boundaries, generally known as Michipicoten. Iron formation rocks outcrop plentifully in this area. Geographically the iron range occurrences fall into three groups, a northern, a central, and a southern. The area is in part traversed by the Michipicoten Division of the Algoma Central and Hudson Bay railway by which access is had to the city of Sault Ste. Marie (distant about 180 miles from the operating mines) and to Michipicoten Harbour on Lake Superior. Information concerning many of the iron deposits in this area is given in a report by A. L. Parsons, published by the Bureau of Mines in 1915.

Northern Section of Michipicoten Area

The northern iron-bearing belt stretches approximately east and west for a distance of about 50 miles, extending from the headwaters of the East Branch of the Pukaskwa river in the District of Thunder Bay through townships 33, 32, 31, 30, 29, 28, and 27, in range XXVI of Algoma. Through this belt the iron formation appears in bands varying from a few feet to over 1,200 feet in width, and in length from a few yards to 3 or 4 miles. Several of these occurrences have appeared sufficiently promising to merit very considerable exploratory work in search of iron ores. The occurrences explored most extensively are the Iron Lake, Frances Mine, Brant Lake, Magpie Mine, Alice, Goudreau, and Morrison properties, the two latter for iron pyrites.

Magpie Mine.—See page 159.

Iron Lake Property.—Iron Lake lies in township 33, range XXVI, Algoma, about 25 miles northwest of Michipicoten Harbour. Iron formation here extends from Bole lake on the west to Red Pine point at the eastern end of McDougall's promontory, a distance of 4 miles. The width ranges from 200 to 1,200 feet, and averages more than 1,000 feet for over half a mile. The general strike of the formation is N. 80°E., and it dips south at angles varying from 55 to 90 degrees. Quartz-porphyry schist and pinkish, yellowish, or greenish felsites are the enclosing rocks. Within the iron formation practically all types of iron formation rocks occur, but the prevailing type is a somewhat impoverished, banded chert, almost always magnetic.

On claims Y 312, Y 313, and Y 315, a considerable amount of stripping was done, much test-pitting carried out, three tunnels driven, and one shaft sunk on small pockets of ore visible on the surface. No ore body of economic interest was found. Pockets of good soft hematite were found here and there in the workings, but with the ore was generally mixed a good deal of chert. Four samples of ore encountered in these workings gave the following results on analysis:

	No. 1 per cent.	No. 2 per cent.	No. 3 per cent.	No. 4 per cent.
Iron	41.20	55.10	48.90	44.10
Silica	37.64	15.02	24.99	32.08
Sulphur	0.022	0.025	0.034	0.020
Phosphorus	0.015	0.043	0.039	0.026
Alumina	0.357	0.126	0.676	0.605
Lime	0.078	0.070	0.070	0.075
Magnesia	Trace	Trace	Trace	Trace
Manganese	None	Trace	None	None

After an interval of several years, exploration was resumed in 1909, five diamond-drill holes with an aggregate footage of 3,500 feet being put down and a considerable amount of trenching done. This work showed only ore pockets similar to those explored by the tunnels and shaft, i.e., none with greater width than 25 feet and all much mixed with chert. No tonnage of ore of economic interest has been found.

REFERENCES: J. M. Bell, Ontario Bureau of Mines, 1905, pp. 317-327.
Records of Exploration, Lake Superior Corporation, Sault Ste. Marie, Ont., 1911.
A. L. Parsons, Ontario Bureau of Mines, 1915, p. 209.

Frances Mine.—The Frances Mine iron range is an irregularly-shaped hill presenting steep cliffs to the north, northwest, and east. It lies about 20 miles north-northwest of Michipicoten Harbour, and about the same distance west of Magpie mine. Banded iron formation, consisting of impoverished banded chert, very ferruginous banded chert or jasper, granular pyritous chert, much oxidized sideritic chert, and a few seams of hematite, are found along this hill. The total outcrop has a maximum width of 935 feet and a length of 1,375 feet.

Several small and unimportant bodies of iron ore occur on the surface. The ore is generally a rich compact hematite. The value of these small deposits is, however, lessened by numerous small horses of jaspery chert. The larger of these ore lenses has a length of 40 feet with a maximum width of 9 feet. The following analysis shows the composition of the hematite:—

	Per cent.
Iron	62.46
Sulphur	0.02
Phosphorus	0.02

Exploration at depth by six diamond-drill holes showed only *pockets* of ore similar to those occurring on surface.

REFERENCES: J. M. Bell, Ontario Bureau of Mines, 1905, pp. 328-329.
A. L. Parsons, Ontario Bureau of Mines, 1915, p. 208.

Brant Lake Property.—Brant lake is a small body of water lying about a mile east and half a mile south of the northwest corner of township 30, range XXVI, Algoma, and about 10 miles northwest of Magpie mine.

About a mile to the northwest of this lake there is a high hill from which diverge in a southeasterly direction several bands of Helen iron formation. Some extend as far as Brant lake, some not so far, and some extend beyond to the east. The iron formation bands consist of rusty, sometimes highly magnetic, banded chert; often soft ore, jasper, sideritic and pyritic chert; rusty quartzitic and granular silica; amphibolitic schist; and small bodies of hydrous hematite and siliceous magnetite.

These iron formation bands are called the Leach Lake bands in the Ontario Bureau of Mines Report for 1905, but the portion of the range explored is known locally as the *Brant Lake property.*

Iron formation band No. 3 (of the Ontario Bureau of Mines Report) is the one around which the greater part of the exploratory work is centred. This band, east of a prominent dike which intersects it, has a length of 1,700 feet and a width varying from 250 to 375 feet; to the west of the dike it is narrower and less attractive.

Exploration in 1902 revealed along the north side of band No. 3 and east of the dike, small deposits of siliceous magnetite. Three samples from outcrops within 125 feet of the dike on analysis showed the following range:—

	Per cent.
Iron	42.00 to 49.00
Silica	25.00 to 39.00
Sulphur	0.06 to 0.14
Phosphorus	0.015 to 0.040

About 400 feet farther east there are small outcrops of magnetite of similar character.

Subsequently (in 1911) three diamond-drill holes were put down on this iron formation band. No. 1 hole, directed under the principal surface showings at an angle of 45 degrees, cut ore from footage 242 to 297 of the following average analysis:—

	Per cent.
Iron	43.14
Silica	14.00
Sulphur	1.544
Phosphorus	0.022

Drill hole No. 2, 300 feet east of No. 1 and dipping under surface showings of lean magnetite cut lean ore from footage 161 to 204 of the following analysis:—

	Per cent.
Iron	31.54
Silica	21.05
Sulphur	2.825
Phosphorus	0.024

Drill hole No. 3 was put down vertically to cut the ore, shown by hole No. 1, at a depth of 500 to 600 feet, if it should extend so far. From 500 to 513 feet the hole cut very lean ore, chiefly siderite, of the following average analysis:—

	Per cent.
Iron	28.56
Silica	22.60
Sulphur	3.438
Phosphorus	0.013
Loss on ignition	8.64

References: J. M. Bell, Ontario Bureau of Mines, 1905, pp. 330-331.
A. Hasselbring for Lake Superior Corporation, Sault Ste. Marie, Ont., 1912.
A. L. Parsons, Ontario Bureau of Mines, 1915, p. 208.

Alice Property (Mining Claims J.L. 88, 89, and 90).—The Alice property lies about a mile south of Magpie mine, and is traversed by the Magpie branch of the Michipicoten Division of the Algoma Central and Hudson Bay railway. On claim J.L. 88 of this property and for a distance of 2,000 feet north along a steep ridge, there are numerous lenses of magnetite of various sizes. Some of these show attractive surface outcrops, the samples assaying as high as 54 per cent. iron. Nearly all, though, carry disseminations and little patches of iron pyrites. One of these magnetite lenses was proven to have a depth of nearly 600 feet, but others were proven to be shallow.

A considerable amount of surface work and 4,858 feet of diamond drilling was done in an attempt to prove up tonnage of merchantable ore, but without success.

Drill holes Nos. 1 and 2 on one ore lens cut respectively 50 and 35 feet of pyritic ore. Representative samples of this ore gave the following average analyses:—

	Hole No. 1 per cent.	Hole No. 2 per cent.
Iron	35.43	39.07
Silica	17.13	21.92
Sulphur	4.47	9.05
Phosphorus	0.012	0.017

Drill holes Nos. 3, 5, and 6 were drilled on another ore lens, Nos. 3 and 5 being vertical. No. 3 cut ore, pyritic magnetite from 26 to 300 feet and from 326 to 586 feet, and No. 5 cut similar ore from 5 to 127 feet, and from 210 to 525 feet. Hole No. 6, dipping at 70°, cross-cut the ore body from footage 262 to 365. Average analyses of the ore cut in these three holes are as follows:—

	Hole No. 3 per cent.	Hole No. 5 per cent.	Hole No. 6 per cent.
Iron	42.57	38.85	32.37
Silica	15.80	19.47	20.35
Sulphur	7.74	2.29	4.918
Phosphorus	0.027	0.025	0.023
Alumina	1.66	2.50	4.20
Lime	5.17	5.77	6.22
Magnesia	3.99	3.98	3.49
Manganese	1.79	2.20	1.02
Loss on ignition	3.03	3.90	5.90

Reference: Records of Exploration, Lake Superior Corporation, Sault Ste. Marie, Ont., 1912.

Besides the occurrences of iron formation just described, there are in the same area numerous occurrences not considered of economic interest. Among these may be mentioned outcrops along *Iron creek* and *Dog river* between Iron lake and Frances mine, others near *Mount Raymond, Morse mountain* and *Lake Charlotte* to the north of the Frances mine, another on *Brotherton hill* to the east of Frances mine, and belts on the north and southeast shores of *Kabenung lake* which converge towards Brant lake.

In the vicinity of Magpie mine there are unimportant outcrops to the northwest of the mine near *Pyrrhotite, Godon* and *Pashoskoota lakes*, to the north along both sides of *Evans creek*, and to the east the *Eccles lake* and *Gravelle claims*, to the southeast along the east bank of the Magpie river, the *Goodwin range*, and to the west the *Gibson claims*.

A few miles to the west and northwest of Goudreau station on the Algoma Central and Hudson Bay railway and about 10 miles northeast of Magpie mine, there is a series of outcrops of banded grey and black chert and magnetite 3 or 4 miles long, portions of which are known as the *Dreany* and *McKay* properties. Though the areal extent of iron formation rocks here is large, there is no sign of concentration on the range.

A mile south of Goudreau station and to the west of the railway, on the *Morrison prospect*, there is a fairly persistent band of iron formation in which it is possible deposits of siderite of considerable size may be shown up.

Central Section of Michipicoten Area

This iron-bearing belt has a length of about 20 miles stretching northeasterly from Little Gros Cap on Lake Superior to township 28, range XXV, Algoma, where its outlying bands seem to merge with outliers of the easterly end of the northern belt. The belt is traversed from end to end by the Michipicoten Division of the Algoma Central and Hudson Bay railway.

The occurrences of iron formation in this belt have attracted a good deal of attention, and very considerable sums of money have been spent in exploring several of them. Those of chief interest are Gros Cap mining location, Helen mine, Johnston locations, Brooks lake claims (Lucy mine), Ruth iron mine (or Long Lake property), Josephine mine, and Bartlett property.

Gros Cap Mining Location.—On the southwest or lakeward side of Little Gros Cap peninsula two excavations over 100 feet long were made and a shaft 64 feet deep sunk on a showing of iron formation. The formation, which has a width of 150 feet, consists of red hematite interbanded with thin layers of chert and granular silica. The thickness of the hematite bands varies from one-half to four or five inches.

Within a short distance two more iron formation bands of no economic interest may be seen.

In the northeasterly part of the location there is an iron formation band about 2,500 feet long striking N. 30°W., the southerly end of which just reaches the shore of Lake Superior. The maximum width appears to be about 150 feet, but the average is probably well under 100 feet. The band is composed principally of sugary, granular silica, often rusty; the northerly end shows banded grey chert. Near its widest part the band shows small concentrations of hematite over an area of 4,500 square feet from which good band specimens may be secured. The enriched portion of the band is, however, badly mixed with silica and has an iron content much too low to make a merchantable ore.

Outcrops of minor significance are reported from the east side of the location near Little Gros Cap Harbour.

REFERENCES: McFarlane, Geological Survey of Canada Report, 1866.
A. B. Willmott, Ontario Bureau of Mines, 1899, p. 145.
L. L. Bolton for Lake Superior Corporation, Sault Ste. Marie, Ont., 1913.

Helen Mine Iron Range.—The Helen Mine iron range lies near the south side of township 29, range XXIV, in the District of Algoma. On it is located Helen mine connected by a short spur with the Algoma Central and Hudson Bay railway, by which access is had to Michipicoten Harbour on Lake Superior, 12 miles distant, and to Sault Ste. Marie, 182 miles distant.

The iron range is 1¾ miles in length, and for a distance of over three-quarters of a mile from the westerly end has an average width of 1,200 feet; in the easterly half, the width decreases gradually from 1,000 feet to a mere point. The range stands about in the vertical, and strikes a little north of east.

The iron formation is composed chiefly of cherty and granular silica, usually massive, but here and there slightly banded. In many places it has been badly crushed and brecciated. In smaller quantities there occur siderite and hematite, which exploration has shown lie exclusively along the south side of the range. With the chert, granular silica, and siderite, there is usually associated more or less pyrite, some of these deposits being of considerable size and of marketable grade. The siderite, as a rule, has a sulphur content below 4 per cent.; but there are considerable tonnages of mixed siderite and pyrite running from 25 to 30 per cent. sulphur.

Helen mine was opened up in 1899 on a deposit of brown hematite located at the east end of Boyer lake near the middle of the range. The first shipments of ore were made in 1900, and except for two intervals, each of about 10 months' duration, the mine was operated continuously until 1918 when the mine was exhausted.

The existence of siderite in the vicinity of the mine has long been known, though it was not until 1910 that attention seems to have been focussed on it. One conspicuous showing is exposed in the railway rock cuts between Boyer and Sayers lakes about 1,700 feet west of the mine. On Mount Hematite, immediately to the east of the mine and 500 feet above the collar of the shaft, the existence of siderite was known from the early days of the mine, but only a meagre amount of work had been done on this showing. Underground development in 1910 and successive years indicated the existence of a considerable tonnage of siderite adjacent to the hematite deposit from the 5th to the 9th levels, i.e., from 375 to 650 feet below the collar of the shaft.

With a view to gaining some additional information concerning the size and character of these deposits, surface exploration and diamond drilling were carried on in 1913 and 1914. (See Helen mine, page 153.)

Helen Mine.—See page 158.

Sayers Lake Siderite Deposit.—About 500 feet west of the siderite outcrop in the railway rock cut between Sayers and Boyer lakes the iron formation was cross-cut by a drill hole 1,081 feet deep. The information gained from this drill hole, coupled with surface indications, suggests that there may be a block of mixed siderite, pyrite, and granular silica, 600 feet long, 200 feet wide, and 150 feet deep, which is equivalent to about 2,000,000 tons. Additional drilling is almost sure to show a tonnage largely in excess of this figure. Of this tonnage a small part is clean siderite, which on calcining would yield an iron ore assaying 50 per cent. or better in iron, and a very considerable part is a mixture of pyrite and siderite with a sulphur content of 25 to 30 per cent. The latter may be of value for its sulphur content, for a somewhat similar grade of heavily pyritized siderite is being mined by the Madoc Mining Company at Goudreau mine (20 miles to the northeast) as a source of sulphur for sulphuric acid manufacture.

Mount Hematite Siderite Deposits.—The siderite stretching eastward from the Helen mine open pit along Mount Hematite was shown by trenching to extend for a distance of 1,300 feet east, and a little to the north of this there is another body of siderite 1,300 feet long with an average width of 160 feet.

An angle drill hole cross-cutting the formation beneath the widest part of the first-mentioned ore body, cut three bands of siderite with widths respectively of 87, 27, and 94 feet, the first two separated by a greenstone band 28 feet wide, and the latter two by a zone of schists 120 feet wide. The hole cut out of siderite at a vertical depth of 750 feet.

A systematic sampling of the siderite exposed in the trenches was made, pop shots being put in to secure unaltered material. Excepting a few "horses" of silica, the siderite is comparatively uniform in composition. The average of 92 samples is as follows:—

	Crude Ore (Actual analysis) per cent.	Roasted Ore (Calculated analysis) per cent.
Iron	35.97	53.37
Silica	6.43	9.54
Sulphur	1.709	......
Phosphorus	0.016	0.024
Loss on ignition	32.60	......

Only ten analys s ran over 4 per cent. sulphur, and the highest sulphur in any one sample was 10 per cent.

The manganese on samples taken from trenches Nos. 4 and 12 ran respectively 2.15 and 2.51 per cent.

The siderite cut in the drill hole was of the following average composition:—

	Crude Ore (Actual analysis) per cent.	Roasted Ore (Calculated analysis) per cent.
Iron	37.97	55.33
Silica	5.82	8.48
Sulphur	2.61	......
Phosphorus	0.010	0.015
Loss on ignition	31.37	......

Further exploration of this deposit has proven a very large tonnage of ore. (See Helen mine, page 159.)

Reference: L. L. Bolton for Lake Superior Corporation, Sault Ste. Marie, Ont., 1914.

Johnston Locations (Mining locations 9 to 14, inclusive).—On the Johnston locations about 3 miles east of Helen mine and a short distance south of Eleanor lake, there are two bands of iron formation. These are composed of banded siliceous material and lean magnetite and hematite on the north side, and massive, siliceous material on the south side. On each there is found

between the banded and the massive silica, a lens of siderite. One of the lenses is at least 600 feet long and 20 feet wide, and the other 250 feet long and 25 feet wide. Grab samples from these showings of siderite were analyzed with results as follows:—

	No. 1 per cent.	No. 2 per cent.
Iron	22.03	34.83
Silica	14.49	8.99
Sulphur	1.91	1.42
Phosphorus	0.014	0.009
Loss on ignition	27.70	31.10
Iron after ignition (calculated)	30.47	50.55

A few pits were put down in the siliceous portions of the iron formation years ago, but no exploratory work has been done to prove up the siderite deposits.

REFERENCES: A. Hasselbring for Lake Superior Corporation, Sault Ste. Marie, Ont., 1912.
A. L. Parsons, Ontario Bureau of Mines, 1915, p. 207.

Brooks Lake Claims (Lucy iron mine).—These claims (situated within 2 miles of the Michipicoten division of the Algoma Central and Hudson Bay railway) include a band of iron formation lying to the north of Brooks lake, located 4 miles northeast of Helen mine. The iron formation band is about 2 miles long, and its width varies from 150 to 800 feet. It is composed of banded ferruginous chert (often much impoverished), soft granular rusty silica, sideritic chert, and siderite.

Trenching across the range has disclosed three lenses of siderite, one 400 feet long by 30 feet wide, a second 1,800 feet long with a width varying from 30 to 100 feet, and a third 1,200 feet long with a width in places of 75 feet. The largest one should yield 1,000,000 tons of siderite with each 100 feet of depth.

The siderite lenses merge into siliceous siderite, into banded iron formation on the north side and at the end, and into sideritic schists on the south. The average of seven samples taken systematically across the three lenses of siderite is as follows:—

	Per cent.
Iron	32.67
Silica	14.19
Sulphur	1.125
Phosphorus	0.072
Loss on ignition	27.47
Iron after ignition (calculated)	45.09

This analysis shows the siderite to be too high in silica and too low in iron to be at present of commercial importance.

REFERENCES: A. P. Coleman, Ontario Bureau of Mines, 1902, p. 161.
Alois Goetz, Engineering and Mining Journal, Vol. 93, p. 1091.
A. Hasselbring for Lake Superior Corporation, Sault Ste. Marie, Ont., 1912.
John E. Kelly, Sault Ste. Marie, Michigan, U.S.A., 1915.
A. L. Parsons, Ontario Bureau of Mines, 1915, p. 21.

Ruth Iron Mine (Long Lake siderite deposits).—The Ruth iron mine is located near the north boundary of township 28, range XXIV, in the District of Algoma. The Michipicoten division of the Algoma Central and Hudson Bay traverses the property, and the distance over this to Michipicoten Harbour on Lake Superior is 21 miles.

The iron formation consists of ferruginous chert, banded and brecciated, granular pyritous chert, and lenses of siderite and pyrite. Trenching, stripping, and a tunnel, located 150 feet beneath the crest of the siderite outcrops, are said to have demonstrated a siderite deposit 2,000 feet long with a maximum width of 200 feet and a usual width of 100 to 140 feet. The tonnage above the tunnel level is estimated at 3,000,000 tons (Alois Goetz). The owner reports the siderite to be of the following average analysis:—

	Per cent.
Iron	35.00
Silica	8.00
Sulphur	Not determined.
Phosphorus	0.012
Lime	5.08
Magnesia	6.71
Manganese	Not determined

REFERENCES: A. P. Coleman, Ontario Bureau of Mines, 1902, p. 173.
Alois Goetz, Engineering and Mining Journal, Vol. 93, p. 1091.
Alois Goetz, private communication, Sault Ste. Marie, Michigan, U.S.A., 1915.
A. L. Parsons, Ontario Bureau of Mines, 1915, p. 210.

Josephine Mine.—This property is located at the westerly end of a range of iron formation, 3½ miles long with general east and west strike, and is covered in part by the waters of Parks and Kimball lakes. It lies in the south part of township 28, range XXV, in the District of Algoma.

A railway spur about one-third of a mile in length connects the property with the Michipicoten division of the Algoma Central and Hudson Bay railway at mile 20 from Michipicoten Harbour on Lake Superior.

The iron formation consists of banded and massive chert, massive jasper, rusty granular chert, sideritic chert, and lenses of hematite and siderite. On the Josephine property it has a width varying between 200 and 400 feet.

No surface outcrops of hematite have been found, but the presence of numerous boulders of good ore on the shore of Parks lake prompted diamond drilling beneath the waters of the lake. About 1902 the sinking of two shafts was commenced, both of which were discontinued and abandoned till exploration by drilling should have proven sufficient tonnage of ore to make a mine. From 1900 to 1905 there were 21 holes drilled, and later, in 1913 and 1914, five additional holes were drilled, the total footage being 17,287 feet.

A deposit of hematite lying on the south side of the iron formation was located by this exploratory work, and its limits were pretty well defined. The deposit probably extends to a depth of 1,200 feet or more beneath the waters of the lake; the extreme length is about 1,100 feet, and the thickness varies from a few inches to 35 feet. Another deposit was cut by two drill holes, but it is too small and lies too deep to be of economic interest.

The owners (Alois Goetz and John McKay) estimate that there is proven 850,000 tons of ore running 59 per cent. iron, a very large percentage of which is of Bessemer grade, and that in addition there is a large tonnage of banded ore capable of being concentrated or roasted.

Another estimate places the proven tonnage at 1,190,500 tons (L. L. Bolton), of which amount only 67 per cent., or 800,000 tons, is recoverable. One-third of the proven tonnage would have to be sacrificed because contamination with iron pyrites and silica would make it unmarketable. The marketable ore, it is estimated, will run 53 per cent. iron (natural) and be of non-Bessemer grade.

The exploration has not given sufficient data for making any estimate of the tonnage of siderite.

REFERENCES: A. P. Coleman, Ontario Bureau of Mines, 1902, p. 173.
Alois Goetz, Engineering and Mining Journal, Vol. 93, p. 1090.
John McKay, Port Arthur, Ont., 1915.
Records of exploration, Lake Superior Corporation, Sault Ste. Marie, Ont., 1914.
A. L. Parsons, Ontario Bureau of Mines, 1915, p. 205.

Bartlett Property.—The Bartlett property lies in the southern part of township 28, range XXV, in the District of Algoma, about one mile north of the Algoma Central and Hudson Bay railway at mile 23 from Michipicoten Harbour on Lake Superior, and about one mile east of Josephine mine.

The iron formation in this property has a length of 1½ miles, and for half this distance has an average width of over 400 feet and a maximum width of about 600 feet. The remainder of the range varies from 50 to 200 feet in width.

The iron formation is composed chiefly of massive granular silica, often rusty, and a more or less continuous band of siderite which lies close to the south side. Pyrite is conspicuous in both the siliceous and sideritic phases of the iron formation.

The property has been extensively explored on surface, showing a body of siderite 1,650 feet or more in length with an average width of more than 50 feet. The average of the analyses of over 40 samples from trenches is as follows:—

	Per cent.
Iron	40.72
Silica	4.61
Sulphur	3.54
Phosphorus	0.008
Loss on ignition	28.59
Iron after ignition (calculated)	57.02

At depth the deposit of siderite was partially explored by four diamond-drill holes with an aggregate footage of 3,817½ feet.

The siderite deposit blends on the south into quartz-porphyry schist, and on the north into siliceous iron formation. It has no clean-cut contacts. Pyrite is present in varying proportions, the sulphur content of 10-foot drill samples varying from 3 to 28 per cent., and in a few places small concentration of pyrites averaging 35 per cent. in sulphur exist. There appears to be no considerable tonnage of siderite with average sulphur content lower than 5 per cent.

In the vicinity of drill holes Nos. 1, 2, and 3 there is proven 2,340,000 tons of siderite averaging 6 per cent. sulphur, which on calcining would run 50 per cent. or better in iron, and probably 1,000,000 tons with a sulphur content averaging 15 per cent.

Elsewhere on the property there is probably 3,500,000 tons of siderite with sulphur content varying from 5 to 20 per cent., which on calcining would run 50 per cent. or better in iron.

Estimates of tonnage by L. L. Bolton from records of exploration.

References: A. Hasselbring for Lake Superior Corporation, Sault Ste. Marie, Ont., 1912.
Records of exploration supplied by Lake Superior Corporation, Sault Ste. Marie, Ont.
A. L. Parsons, Ontario Bureau of Mines, 1915, p. 210.

In the central section of the Michipicoten iron area there are numerous occurrences of iron formation of lesser importance than those just described.

East of Michipicoten Harbour and within 1½ miles of it, there are three outcrops, one known as the *Gibson prospect*, none of which are of economic interest.

References: A. P. Coleman, Ontario Bureau of Mines, 1902, p. 160.
Jas. Bartlett for Lake Superior Corporation, Sault Ste. Marie, Ont., 1913.

About 3 miles northwest of Helen mine is located the *Mildred property* including an outcrop of iron formation 1¾ miles long. The range varies in width from 150 to 600 feet, and it consists of quartzitic and granular silica and some magnetite, pyrite, and impure siderite.

References: A. P. Coleman, Ontario Bureau of Mines, 1906, p. 181.
M. C. H. Little for Lake Superior Corporation, Sault Ste. Marie, Ont., 1912.
Alois Goetz, Engineering and Mining Journal, Vol. 93, p. 192.

The *Arnott claims* include an iron range 1½ miles long lying parallel to the Brooks Lake claims (Lucy mine) and three-quarters of a mile north of them. The iron formation is composed chiefly of granular silica, often rusty, and siliceous siderite, with here and there small pockets of iron pyrites.

References: Peter Arnott, Helen mine, District of Algoma, Ont., 1915.
W. M. Goodwin for Lake Superior Corporation, Sault Ste. Marie, Ont., 1912.
A. L. Parsons, Ontario Bureau of Mines, 1915, p. 209.

About 2 miles north of the Josephine-Bartlett iron range, outcrops of iron formation are picked up in line from east to west for about 4 miles. The series of outcrops is known locally as the *Brooks iron ranges*.

The iron formation is composed chiefly of granular, massive, and banded silica, and in a subordinate proportion of lenses of siderite and pyrite, usually intermixed. Towards the easterly end there are 5 such lenses with lengths varying from 150 to 500 feet and with average widths of from 15 to 25 feet. The most highly pyritized lenses run about 32 per cent. sulphur, 43 per cent. iron, and 25 per cent. loss on ignition. Near the centre of the range there are two siderite lenses, one 400 feet by 30 feet and another 100 feet by 45 feet. Towards the westerly end there are several lenses of siderite, the largest 400 feet long and from 10 to 20 feet wide. One lens, 120 feet long by 10 feet wide, is unique in that it lies entirely apart from iron formation rocks as does the Magpie mine ore body.

Reference: E. L. Goodwin for Lake Superior Corporation, Sault Ste. Marie, Ont., 1912.

While not strictly belonging to the central section of the Michipicoten iron area, the *Dog River claims* may best be considered here. They lie on the Lake Superior shore about 16 miles west of the Gros Cap outcrops and are comparatively isolated from other iron range outcrops.

Iron formation outcrops are picked up not far from shore about 4 miles west of Dog river and they may be followed north and northwest for about 2 miles. The iron formation consists of banded white and grey chert and magnetite. A little specular hematite is exposed in some shallow workings. The greatest width of iron formation is under 200 feet. The occurrence is of no economic interest.

References: J. M. Bell, Ontario Bureau of Mines, 1905, pp. 316 and 337.
L. L. Bolton for Lake Superior Corporation, Sault Ste. Marie, Ont., 1910.

Southern Section of the Michipicoten Area

The southern section of the Michipicoten area stretches from Lake Superior on the west to the main line of the Algoma Central and Hudson Bay railway on the east, a distance of about 20 miles, and southerly from the Michipicoten river for about 16 miles. The northwest corner of the section is within 4 miles of Michipicoten Harbour in the central section of the Michipicoten iron area.

Through the southern section iron formation outcrops are scattered quite plentifully, but generally without much regularity as to strike or continuity.

South of Michipicoten river banded iron formation is reported in several points near *Bridget lake* where it can be followed in one place from northeast to southwest for about 200 paces, but with very unequal widths. It consists in some cases of black, cherty-looking material with considerable magnetite, in others of a fine sandy-looking rock with little magnetite.

South of Bridget lake small outcrops of banded iron formation are found at the west end of *Junction lake*, at each end of *Island lake*, and between *Peters lake* and *Centre lake*. All these outcrops are of the sandy variety and without much promise of ore.

At the *outlet of Island lake* into Noisy river an occurrence of magnetite interbanded with a green silicate, some of which may be rich enough in iron to constitute an ore, is reported.

Farther south to the west of *Lake Mijinemungshing* a number of claims have been located on iron formation which is very lean in iron.

About 2 miles southeast of *Cap Choyye* a small deposit of impure hematite occurs, but the amount to be seen is too small to give the deposit any practical importance.

Just east of *Anjigomi lake*, at mileage 146.5 on the Algoma Central railway, the most westerly of a series of iron formation bands is exposed in a rock cut. These bands are picked up towards the northeast for about three-quarters of a mile. The bands are not continuous for very long distances and the widths are usually under 20 feet. The largest exposures lie near the railway where there is a zone of iron formation rocks 50 feet wide which includes several bands of rock.

The iron formation is composed of white, grey, and black chert interbanded, granular silica, both massive and banded, and pyrite and magnetite. Pyrite in small grains or narrow bands is plentifully present. Magnetite usually occurs in narrow bands, but at one point near the railway track a siliceous phase of it constitutes nearly the whole width of the iron formation band. The enriched portion of the band has been test-pitted, and a sample across a width of 35 feet is reported to have assayed as follows:—

	Per cent.
Iron	46.90
Silica	23.00
Sulphur	0.68
Phosphorus	0.11

This is too low grade for present furnace requirements, and there is no considerable quantity of it. Because of the limited extent of the iron formation outcrops and lack of evidences of concentration, there seems no probability of any deposits of ore of economic interest existing here.

About 4 miles west of the Anjigomi claims, there is an outcrop of iron formation of considerable size along the boundary between townships 28 and 29, range XXII. About 3 miles farther west, near *Lake Mishewawa*, there occur a few small outcrops. A little to the north of this lake, a belt of iron formation is picked up which stretches northwesterly for 2 miles, with a width of a quarter of a mile, and crosses the Michipicoten river just below *High Falls*.

On Devil's Warehouse island, near *Cape Gargantua*, there is a vein of calcite and barite in which there are pockets of high-grade hematite, but none of these are large enough to be of economic interest.

REFERENCES: A. P. Coleman, Ontario Bureau of Mines, 1906, pp. 177-181.
E. S. Moore, Ontario Bureau of Mines, 1906, p. 204.
B. E. Lalonde for R. H. Flaherty, Port Arthur, Ont., 1909.
L. L. Bolton for Lake Superior Corporation, Sault Ste. Marie, Ont., 1912.

BATCHAWANA RIVER AREA

In *Palmer township* (about 35 miles north of Sault Ste. Marie, Ont.), two iron ranges have been located, one not far north of the south boundary of the township, and about 7 miles from Batchawana village on Lake Superior, and the other 5 or 6 miles farther north along the north boundary of the township.

The southern range (referred to locally as the *Batchawana mine*) is picked up at intervals for a distance of about 5 miles from east to west. The iron formation is composed chiefly of dull red jasper with which is associated some hematite and a very little magnetite. The jasper has undergone dislocations since it was formed and is in lenticular bands, sometimes brecciated, with the fissures filled with specular hematite. No work has been done to demonstrate the extent of the iron formation occurrences.

The northern range is mostly included in mining locations known as the *Heck lands*, of which the *Mammoth Mountain* and *Vulcan locations* have attracted most attention.

On this property there are two bands of iron formation a quarter of a mile apart and paralleling one another. The iron formation outcrops are very siliceous, being composed of alternating bands of light and dark-coloured granular silica and lean and high-grade magnetite, the average thickness of the bands being about one-half inch. At some exposures, magnetite constitutes 50 per cent. of the rock, and specimens of magnetite running 50 per cent. iron may be secured.

The small amount of exploratory work done is entirely too little to demonstrate the areal extent of the iron formation, but it is undoubtedly large, one estimate being 75 acres. It is improbable that any large tonnage would average more than 35 per cent. iron. Pyrite is present in sufficient quantity to give in all probability an undesirably high sulphur content.

REFERENCES: A. P. Coleman, Ontario Bureau of Mines, 1901, pp. 189-190.
G. M. Stewart for Lake Superior Corporation, Sault Ste. Marie, Ont., 1902.
B. E. Lalonde for R. H. Flaherty, Port Arthur, Ont., 1909.
R. S. Rose, Marquette, Michigan, U.S.A., 1910.
A. P. Coleman, Ontario Bureau of Mines, 1914, p. 207.

In township 26, range XIII, about 7 miles southwest of Batchewana station on the Algoma Central and Hudson Bay railway, are located the *McGovern iron claims*. On these there occur several narrow bands of iron formation, only one of which exceeds 50 feet in width and the majority of which are less than 25 feet wide. Nor are the bands continuous for long distances.

Nearly all the outcrops of iron formation are composed of light to dark grey, and black chert, and siliceous magnetite. The formation is banded, the bands being usually less than three-quarters of an inch thick. One band, with a maximum width of 100 feet, is composed of rusty granular silica through which pyrite is plentifully disseminated in small grains.

REFERENCE: L. L. Bolton for Lake Superior Corporation, Sault Ste. Marie, Ont., 1913.

In township 24, range XV, about 10 miles northeast of Pangis station on the Algoma Central and Hudson Bay railway, are located the *Drury iron claims.* Stretching through these is a belt of iron formation composed of banded magnetite, dark jasper, and schist. The occurrence is of no economic interest.

REFERENCE: B. E. Lalonde for R. H. Flaherty, Port Arthur, Ont., 1909.

UPPER GOULAIS RIVER AREA

McClintock Claims.—These are located near the centre of township 22, range XIII, about 12 miles east and 4 miles north of Alva station on the Algoma Central and Hudson Bay railway.

The iron ore occurrences are located in pegmatitic granite. Small seams of iron ore, principally hematite, and bunches of ore up to one foot in diameter are scattered through the rock. They make up perhaps 5 per cent. of the rock. While the ore is of good quality, the quantity is altogether insignificant, and the mode of occurrence gives little promise of any larger quantity. One occurrence on these claims north of the Goulais river, is in a band of amphibolite enclosed in granite. But this is equally unpromising.

REFERENCE: J. A. Dresser for Lake Superior Corporation, Sault Ste. Marie, Ont., 1913.

Goulais River Iron Range.—This is a range of iron formation lying just south of the Goulais river in township 22, range XII, and township 22, range XIII, and 9 miles east of Alva station on the Algoma Central and Hudson Bay railway. The northerly part of the range is included in the *Hilliar iron claims.*

The range strikes a little west of north. It has a length of about 2 miles, and the width in places exceeds 400 feet, but enclosed in it there are often bands of rock. The country rock to the west is in all cases greenstone, and to the east usually granite. The granite has intruded into the iron range in many places, and small bands of iron ore are found in the granite by which they have been separated from the main body. Dikes of granite also cut the ore body which is in places much twisted and contorted, and so becomes very irregular in strike.

The iron range forms a high, steep ridge, in places 400 to 500 feet above the Goulais river, and is crossed by several ravines, 200 to 300 feet deep, which have very steep faces on the southeast sides. The greatest depth to which iron formation is exposed by these ravines is nearly 500 feet. Six hundred yards south of the Goulais river, the entire range is cut off abruptly, evidently by a fault, at what is probably its greatest width. No trace of it has been found to the north for at least 10 miles. At the southerly end the range narrows and dies out in narrow stringers.

The various outcrops show banded iron formation. Generally, siliceous bands compose nearly two-thirds of the whole formation, and bands of lean magnetite the remainder. The magnetite bands contain fine grains of quartz and silicates which can be seen only on close examination, and they usually blend into the siliceous bands. Occasionally bands of clean magnetite two or three inches wide are seen. The silica is usually granular, is white, light and dark grey, or black in colour, and at one point a little jasper is exposed.

There is in the range a large amount of material which should run 35 per cent. iron, and an enormous quantity of nearly or quite 30 per cent. grade. Except in a few very small areas where there is local fissuring, there is no reason to expect a better grade of ore.

Quite a little surface exploration has been done on the range, and a ten-ton sample of representative material was sent to the ore-dressing plant of the Mines Branch, Ottawa, for concentration tests.

Because of the siliceous character of even the richest magnetite bands, the Gröndal process was considered the only one feasible for this ore. The results of the experiments were disappointing; for even after crushing till 76 per cent. passed 200 mesh, the iron contents of final concentrates from two experiments ran only 53.5 per cent. and 53.6 per cent. iron, respectively.

REFERENCES: D. B. Rockwell for R. H. Flaherty, Port Arthur, Ont., 1910.
L. L. Bolton for Lake Superior Corporation, Sault Ste. Marie, Ont., 1910.
J. A. Dresser for Lake Superior Corporation, Sault Ste. Marie, Ont., 1913.
Geo. C. McKenzie, Mines Branch, Summary Report, 1911, pp. 71-75.

DEROCHE TOWNSHIP AREA

Williams Mine.—This mine is located close to the southeast corner of Deroche township and is about 2½ miles southeast of Northfield (formerly Wilde) station on the Algoma Central and Hudson Bay railway, which is 24 miles from Sault Ste. Marie. Ont.

The ore bodies on this property lie in a belt of slate and quartzite. They are prevailingly narrow, and usually blend into siliceous country rock. The ore consists of iron black, and lustrous, specular hematite. A shaft was sunk to a depth of 200 feet, and several hundred feet of drifting and about 1,500 feet of diamond drilling was done.

In 1905, small shipments of ore were made to the steel plant at Sault Ste. Marie; but the results of exploration in 1904 and 1905 seem to have been discouraging, for the mine has been idle since March, 1905.

REFERENCES: W. E. H. Carter, Ontario Bureau of Mines, 1904, part I, p. 75.
W. E. H. Carter, Ontario Bureau of Mines, 1905, part I, p. 59.
E. T. Corkill, Ontario Bureau of Mines, 1906, p. 71.

Breitung Mine.—This mine, at one time called the Loon Lake mine, is situated on Loon lake about 1½ miles southeast of Northfield station on the Algoma Central and Hudson Bay railway.

The ore formation is a greyish slate with a width of 300 to 400 feet. Through this there are pockets and streaks of hematite of varying degrees of purity.

The largest ore body explored had a width of 50 feet. The central portion of this ore body was clean ore, but on the south side particularly the ore became increasingly siliceous.

A shaft was sunk to a depth of 175 feet, a tunnel was driven about 300 feet, a few hundred feet of drifting was done, and a small tonnage of ore was stoped. In 1905 a little ore was shipped to the steel plant at Sault Ste. Marie, probably between 2,000 and 3,000 tons. The mine has been idle since 1905.

REFERENCES: W. W. J. Croze for R. H. Flaherty, Port Arthur, Ont., 1901.
W. E. H. Carter, Ontario Bureau of Mines, 1904, p. 75.
E. T. Corkill, Ontario Bureau of Mines, 1906, p. 71.

Hawkshaw-Derrer Property.—This property lies along the Algoma Central and Hudson Bay railway, within 1½ miles of Northfield station, and it corners on the Breitung property to the southeast.

Outcrops of specular hematite of exceptionally good quality prompted a considerable amount of surface work and diamond drilling in search for ore deposits here. The exploration demonstrated that hematite occurred only as enrichments in quartz veins varying from 2 to 8 feet in width, and as fillings in torsion cracks in granite. Neither mode of occurrence gives any promise of furnishing tonnage of economic interest. The quartz veins are found in quartzite and grey slate, and their strike is conformable with that of the enclosing rocks.

REFERENCES: L. L. Bolton for Lake Superior Corporation, Sault Ste. Marie, Ont., 1910.
G. R. McLaren for Lake Superior Corporation, Sault Ste. Marie, Ont., 1910.

Moran-Ferguson Property.—This lies immediately south of the Hawkshaw-Derrer property, and within 2 miles of Northfield station.

Quartzite, grey slate, and granite are the rocks exposed. In the quartzite there is a ferruginous zone with a width of 4½ feet, through which specular hematite is scattered in little pockets. In the quartzite, there are also long, narrow lenses of red hematite, but none wider than 10 inches was exposed. The ore showings offer no reason for expecting any tonnage of interest.

REFERENCE: A. Hasselbring for Lake Superior Corporation, Sault Ste. Marie, Ont., 1910.

Poitras-Watt Claims.—These lie near Bellevue station on the Algoma Central and Hudson Bay railway, and about 2 miles west of the Moran-Ferguson property just described.

In the quartzite occurring on this property, there are small areas showing concentrations of red hematite. Generally the hematite is decidedly siliceous, and the proportion of clean hematite in any pocket is insignificant. A sample of the ore exposed in one showing is reported to have given the following analysis, which appears to indicate fairly the character of the ore occurring here:—

	Per cent.
Iron	36.50
Silica	48.58
Sulphur	0.089
Phosphorus	0.005

REFERENCES: B. E. Lalonde for R. H. Flaherty, Port Arthur, Ont., 1909.
L. L. Bolton for Lake Superior Corporation, Sault Ste. Marie, Ont., 1909.

The *Bell Hematite prospect* is located in lot 2, concession II, Deroche township. Here steel-grey hematite is found in small pockets in a narrow quartz vein, and in hornblende schist, a mode of occurrence offering no promise of tonnage. The ore-bearing area, also, is too small to admit of any considerable tonnage.

REFERENCE: L. L. Bolton for Lake Superior Corporation, Sault Ste. Marie, Ont., 1910.

On the *McCauley claims*, 2 miles south of Bellevue station, there is an outcrop of titaniferous magnetite, too small to be of interest. A sample from the ore outcrop gave the following analysis:

	Per cent.
Iron	39.00
Silica	5.40
Sulphur	0.370
Phosphorus	0.015
Lime	0.50
Titanium dioxide	4.25

REFERENCE: L. L. Bolton for Lake Superior Corporation, Sault Ste. Marie, Ont., 1911.

On the *Legge farm*, within a mile of Bellevue station, there occurs in the quartzite a quartz vein carrying small pockets of hematite. The occurrence is of no economic interest.

REFERENCE: L. L. Bolton for Lake Superior Corporation, Sault Ste. Marie, Ont., 1913.

Campbell Iron Claims.—Near the northwest corner of Deroche township are located the principal ore occurrences showing on the Campbell iron claims. The property is reached by trail from Wabos station (mile 35) on the Algoma Central and Hudson Bay railway.

Strippings show that banded iron formation outcrops are fairly plentiful over an area measuring 200 feet by 1,500 feet. The probability is that in this area there are many small discontinuous bands of iron formation with nearly parallel strike. The best cross-section exposed in the surface operation is as follows:—

12 feet, greenstone.
53 " banded iron formation.
25 " greenstone.
6 " lean iron formation, slaty and pyritic.

The iron formation is composed of alternating bands of granular silica and magnetite, the limits of the latter being rarely clean cut. At the largest exposure the siliceous part of the formation is mostly red garnet. Average samples from two test pits put down here showed the iron content to be about 30 per cent. A sample taken across a width of 55 feet of iron formation (B. E. Lalonde), gave the following analysis:—

	Per cent.
Iron	34.13
Silica	46.50
Sulphur	0.27
Phosphorus	0.11

A small shipment of siliceous ore was made to the American Gröndal Company for experiments in magnetic concentration. The Gröndal Company report that by grinding to 60-80 mesh a 63 per cent. magnetic concentrate can be secured, the ratio of crude ore to concentrate being 2 to 1. The analyses of crude ore and concentrates are reported to have been as follows:—

	IRON per cent.	PHOSPHORUS per cent.
Crude ore	38.20	0.110
No. 1 concentrate	55.67	0.060
No. 2 concentrate	63.57	0.050
Tailings	14.92	0.150

REFERENCES: L. L. Bolton for Lake Superior Corporation, Sault Ste. Marie, Ont., 1907.
B. E. Lalonde for R. H. Flaherty, Port Arthur, Ont., 1909.
R. R. Rose for Lake Superior Corporation, Sault Ste. Marie, Ont., 1914.
American Gröndal Company for E. A. Sjostedt, Sault Ste. Marie, Ont., 1911.

AWERES TOWNSHIP

Near *Granite station* on the Algoma Central and Hudson Bay railway, and about 8 miles north of Sault Ste. Marie, there is an iron formation outcrop disclosing cherty or quartzitic silica, interbanded with magnetite. The general strike is N. 20°W., but as the belt is much contorted and penetrated by granite, the strike is far from uniform. The deposit is not large and is too siliceous to be of use as an ore.

REFERENCES: A. P. Coleman, Ontario Bureau of Mines, 1901, p. 197.
A. P. Coleman, Ontario Bureau of Mines, 1914, pp. 207-229.

In the northwest quarter, section 2, near Island lake, Charles Burkland has uncovered a small area of quartz, through which is scattered a little hematite, and a portion of which is of the specular variety.

REFERENCE: L. L. Bolton for Lake Superior Corporation, Sault Ste. Marie, Ont., 1912.

MACDONALD TOWNSHIP

On section 22 (Rulidge property), a vein carrying a little hematite outcrops at several places. The country rock is quartzite.

REFERENCE: G. L. Michael for Lake Superior Corporation, Sault Ste. Marie, Ont., 1909.

On the southeast quarter, section 29, is located the *Osborne prospect.* Along the contact between the red and white quartzite there is a zone, in places 70 feet wide, which is heavily stained with red oxides of iron. In certain sections of this zone the rock has been fractured and re-cemented with hematite; while small fragments of good ore may be secured, the proportion of clean hematite is not more than 1 in 15.

Reference: L. L. Bolton for Lake Superior Corporation, Sault Ste. Marie, Ont., 1908.

On the *Armstrong-Henry property* (section 36) a shaft was sunk 18 feet on a hematite prospect. Seams of hard, rich, specular ore are found. One diamond-drill hole was put down about 280 feet. No encouraging results were secured.

Reference: P. A. Gough for R. H. Flaherty, Port Arthur, Ont., 1900.

MEREDITH TOWNSHIP

Section 31 is known as the *Armstrong-Henry property.* Here a couple of shallow shafts and some test pits were sunk on showings of hard and soft hematite occurring in quartzite. A diamond-drill hole showed only 15 inches of good ore beneath the best surface showing. Exploration was discontinued because of discouraging results.

Reference: J. Kellerschon for R. H. Flaherty, Port Arthur, Ont., 1900.

ABERDEEN AND ABERDEEN ADDITIONAL TOWNSHIPS

The *Palms property* (lot Y-8 Aberdeen) lies about $8\frac{1}{2}$ miles north of Desbarats station on the Canadian Pacific railway. On a hematite showing here, three diamond-drill holes were put down and a trench 75 feet long excavated. The quartzite in which the exploration was made, shows only seams of very lean ore, and discolorations of red oxide.

Reference: P. A. Gough for R. H. Flaherty, Port Arthur, Ont., 1900.

Stretching through *lots 11 and 12, concession IV* (*Aberdeen*), the north halves of *lots 1, 2, and 3, concession IV*, and the south half of *lot 3, concession V*, (*Aberdeen Additional*), there is a belt of grey slate in which there is a ferruginous zone along the contact with the quartzite to the southwest. In this zone the hematite where it occurs in pockets or veins is iron-black and bluish in colour, and compact, and where disseminated is of the specular variety. The best showing (not over 100 feet in length) has a maximum width of 6 feet of merchantable ore, and on either side the ore becomes increasingly siliceous. A shaft, 32 feet deep (on the south half, lot 12), encountered seams of high-grade specular ore from 6 inches to 4 feet in width.

Four diamond-drill holes with an aggregate depth of 1,000 feet were put down in 1903 to explore the most promising portions of this ore band. Iron ore was encountered in three holes at depths of 150, 60, and 160 feet, respectively. At these depths the respective widths of the ore were as follows: 3 bands, 1 foot wide, in an 8-foot width of the formation; 2 bands, 2 feet wide, separated by 2 feet of quartzite; and 10 feet in one band. The slate on one or both sides of the iron-bearing quartzose rock is ferruginous for widths of several feet.

On lot 6, concession III (Aberdeen Additional), there is a white quartzite occasionally stained red with earthy hematite and containing thin seams of specular hematite.

References: P. A. Gough for R. H. Flaherty, Port Arthur, Ont., 1900.
A. P. Coleman, Ontario Bureau of Mines, 1901, p. 188.
W. E. H. Carter, Ontario Bureau of Mines, 1904, p. 76.

At the *Stobie iron mine* near the west end of Gordon lake, mining operations were carried on between 1874 and 1878. Hematite was extracted by two tunnels from a vein with width varying from 2 to 11 feet. Several vessel loads of ore were shipped to Detroit.

References: Ontario Bureau of Mines, 1892, p. 64.
Geological Survey of Canada, Annual Report, Vol. XV, 1902-03, p. 253A.

LAIRD TOWNSHIP

On the southeast quarter of section 3 (*Howard farm*) and on the northwest quarter of section 12 (*Garnett farm*, near Labester, P.O.), the rocks exposed are quartzite and conglomerate. These in places show reddish discoloration from the presence of reddish iron oxides, and narrow films and streaks of specular hematite.

Reference: L. L. Bolton for Lake Superior Corporation, Sault Ste. Marie, Ont., 1911.

JOHNSON TOWNSHIP

At different points on the *Desbarats location*, hematite, some of it of the specular variety, is found in red quartzite occurring both disseminated through the rock and segregated in veins and pockets. On lot 22, close to Desbarats station, a shaft 8 by 8 feet and 25 feet deep cut

streaks and pockets of good ore. Another shaft 10 by 9 feet and 10 feet deep showed four hematite veins with widths of 5, 8, 12, and 15 inches, respectively. On lot 32 a vein of micaceous specular hematite averaging 20 inches in width was traced for 200 yards.

At a later date (in 1897), additional exploration was done in this vicinity for iron ore, but apparently without satisfactory results.

References: R. G. Leckie and John Wearne for the owners, 1874.
A. Mackenzie for the owners, 1891.
A. Slaght, Ontario Bureau of Mines, 1897, p. 97.

PARKINSON TOWNSHIP

On the north half of the south half, *lot 7, concession I*, several parallel bands of lean magnetite occur in a dark hornblendic rock, the exposure being a rocky bluff with a face 50 feet high.

Reference: D. B. Rockwell for R. H. Flaherty, Port Arthur, Ont., 1910.

LONG TOWNSHIP

On *location X*, near Algoma Mills, a little exploration has been done on a hematite prospect. The ore, which is of good grade, occurs in innumerable small veins only a few inches in width scattered irregularly through a diabase outcrop 120 feet long and 30 feet wide.

Reference: A. Hasselbring for Lake Superior Corporation, Sault Ste. Marie, Ont., 1907.

TOWNSHIPS NOS. 163 AND 169

Mining locations T.P. 25 and 26 and eight adjacent claims cover an area one-quarter of a mile wide by 2¾ miles long. This area includes a fractured zone in greywacké, the prevailing country rock, probably fairly continuous, which is filled with secondary quartz and specular hematite in varying proportions. A cross trench on the best exposure shows 5 feet of specular hematite with some lustreless magnetite and some easily discernible quartz and calcite, the quartz and calcite forming 15 to 20 per cent. by volume of the whole. From all indications the hematite is not likely free enough from impurities nor present in large enough quantity to be of economic interest.

Reference: L. L. Bolton for Lake Superior Corporation, Sault Ste. Marie, Ont., 1911.

MISSISSAGA FOREST RESERVE

Townships 3F and 4F are underlain by granite and gneiss exclusively. In these rocks there are numerous diabase dikes, a few of which have widths of 100 feet. Near the contacts of the diabase with the granite there are quartz veins, occasionally 10 inches wide, with small quantities of pyrite, chalcopyrite, and specular iron ore. In several cases fine specimens of the latter could be obtained from the veins, but the total quantity in any vein seen was too small to be of economic importance.

Reference: Jas. Bartlett for Lake Superior Corporation, Sault Ste. Marie, Ont., 1911.

6. District of Manitoulin

Frazer Bay Claims.—This property lies on Frazer bay, an arm of Georgian bay, and is about 15 miles east of the town of Little Current on Manitoulin island. It includes an area of white quartzite on the north shore of Frazer bay, in which there are zones of iron-bearing slate. The area measures about 1 mile from north to south and 4 miles from east to west.

At the best-looking exposure, a rock excavation 2 to 4 feet deep across the iron-bearing zone, shows 30 feet of iron-bearing slate, 3 feet of quartzite, and 6 feet of iron-bearing slate. In the slate bands there are bands of siliceous, specular hematite with slaty cleavage varying from 1 inch to 1 foot in thickness. In vertical cross-section the width of the ore bands is seen to be very irregular. The best-looking bands do not constitute more than one twenty-fifth of the whole slate band. A sample of the hematite at this exposure gave the following analysis:—

	Per cent.
Iron	29.73
Silica	54.88
Sulphur	0.035
Phosphorus	0.033

On cleavage faces lumps of ore present a high-grade appearance, but the other faces are dull and earthy.

In addition to the outcrop described, there are many of lesser importance, and many of the claims are staked on outcrops of slate which do not carry any iron ore.

In 1914 the property was explored by diamond drill.

References: L. L. Bolton for Lake Superior Corporation, Sault Ste. Marie, Ont., 1912.
C. W. Knight, Ontario Bureau of Mines, 1915, p. 228.

7. District of Sudbury

CHAPLEAU AREA

McVittie Locations near Nemegos Station.—These locations (W.D. 275 and 276) are situated in the township of McNaught, about 5 miles northeast of Nemegos station on the main line of the Canadian Pacific railway.

Syenite, often porphyritic, is the rock nearly everywhere exposed in this vicinity. In smaller proportion appear granite and a dark basic-looking rock, possibly a recrystallized gneiss or schist. A thin section of the latter was found to be composed of 35 per cent. hornblende, 35 per cent. quartz, 20 per cent. orthoclase, and 10 per cent. magnetite. A sample of this rock carried 8.81 per cent. iron, and 0.31 per cent. titanium dioxide. The presence of this small proportion of magnetite is probably accountable for the feeble attraction for the magnetic needle observed at different points where the rock was obscured by drift.

In the dark-coloured rock there are numerous pockets of lustrous titaniferous magnetite. These pockets vary from the size of a plum up to one showing a cross-section with an area of 90 square feet. The ore everywhere seems uniform in texture and composition. The boundaries of the ore pockets seem devoid of any regularity. In quarrying there is no tendency for ore to break free from the country rock.

A few trenches and test pits have been dug, and from the largest outcrop a shipment of about 125 tons of ore was made.

From the surface work and a magnetic survey, it appears that the ore outcrops are portions of small, isolated deposits, connected in some instances by rock formation carrying a little magnetite. Indications hardly warrant the expenditure of much money for diamond drilling or development.

Analyses of three samples are given below, No. 1 being a sample from ore stock piled at the railway in April, 1910, and Nos. 2 and 3 being general samples taken from natural ore outcrops in 1909.

	No. 1 per cent.	No. 2 per cent.	No. 3 per cent.
Iron	61.50	63.5	51.81
Titanium dioxide	11.50	12.5	11.91
Silica	3.25	......	......
Sulphur	0.022	......	......
Phosphorus	0.010	......	......

References: B. F. Haanel, Mines Branch, Summary Report, 1909, p. 110.
L. L. Bolton for Lake Superior Corporation, Sault Ste. Marie, Ont., 1910.

WOMAN RIVER AREA

The Woman River iron ranges are included in a belt of territory which extends from the northeast end of Rush lake southwesterly across the Rush river, and along the Woman and Ridout rivers to a point about eight miles northeast of Ridout station on the Canadian Pacific railway main line, a distance in all of about 40 miles.

The most attractive-looking portions of the iron range outcrops have been staked for iron, and the principal holdings from northeast to southwest are known respectively as the Smith, Leith, Drummond, Dobie, McLaren, and Marks claims.

Smith Claims (*Jefferson Iron Mine*).—These extend with a trend slightly south of west from the northeast end of Rush lake to the Rush river, a distance of about three miles. The distance south by canoe route to Bisco on the Canadian Pacific railway main line is approximately 60 miles. The Canadian National transcontinental line lies about 20 miles to the east.

Except for a few short intervals, a band of iron formation can be traced for the whole length of the property. The iron formation, which varies from a few feet to 300 feet in width, is composed of cherty and granular silica, generally banded, and along its south side are found irregularly-shaped lenses and pockets of intermixed magnetite, pyrite, and pyrrhotite. The desposits at the easterly end of the property have the highest iron content and are best described as lenses of magnetite impregnated fairly uniformly with pyrite and pyrrhotite. Following the range westward the proportion of pyrite and pyrrhotite increases, and some outcrops show a fairly good grade of pyrite.

A considerable amount of trenching and diamond drilling has been done on the property, showing large tonnages of mixtures of magnetite, pyrite, and pyrrhotite of varying proportions.

The best-looking deposit of magnetite has an average width of from 35 to 40 feet and a length of 4,000 feet. At two points, about 1,700 feet apart, it is proven to maintain its surface width at depths of 300 and 380 feet respectively.

Three analyses which demonstrate fairly clearly the chemical composition of this ore are given herewith. No. 1 represented the ore cut in drill hole No. 3, from 230 to 405 feet; No. 2 the ore cut in drill hole No. 4, from 280 to 330 feet; and No. 3 was a chip sample from trenches on the ore deposit.

	No. 1 per cent.	No. 2 per cent.	No. 3 per cent.
Iron	36.23	35.93	41.28
Silica	15.55	11.25	16.55
Sulphur	20.76	21.30	17.17
Phosphorus	0.016	0.011	0.016
Alumina	0.293	......	......
Lime	0.77	......	......
Magnesia	4.87	......	......
Manganese	0.40	......	......
Loss on ignition	13.00	......	......

A pyritic ore body farther west, with a width of 37 feet but probably not of great length, was cut at depth by two drill holes. One of these cut lean banded ore from 105 to 187 feet (equivalent to a horizontal width of 45 feet), of the following analysis:—

	Per cent.
Iron	29.00
Silica	10.40
Sulphur	1.078
Phosphorus	0.015

Samples from three of the most pyritic ore bodies containing any tonnage of interest gave the following analyses:—

	No. 1 per cent.	No. 2 per cent.	No. 3 per cent.
Iron	23.89	22.60	20.15
Silica	4.20	8.15	8.15
Sulphur	23.78	19.92	20.10
Phosphorus	0.004	0.006	0.008

REFERENCES: L. L. Bolton for Lake Superior Corporation, Sault Ste. Marie, Ont., 1910.
H. Bradley for R. H. Flaherty, Port Arthur, Ont., 1922.
W. E. Smith, Sudbury, Ont., 1914.

Leith Claims.—The Leith claims are the next group west of the Smith claims, and they cover the iron range outcrops for a distance of about 6 miles, the strike of which in this property is approximately northeast and southwest. The Rush river passes just east of the claims, and the Woman river crosses them about 2 miles further west.

East of the Woman river the iron range is not well defined. To the west it occurs in three main belts. No. 1 belt, the most westerly, lies in claims W.S. 10, 11, and 12. Its strike is northwest and southeast at right angles to the general trend of the range. Its length is about one mile, and its extreme width about 850 feet. Belt No. 2 is in claims W.S. 9 and 8. The length from northeast to southwest is about three-quarters of a mile, and the maximum width is 1,400 feet. Belt No. 3, extending through claims W.S. 8, 7, 4, 5, and 6 has a slight break in W.S. 7. The southwesterly portion (in W.S. 7) strikes about north and south, has a length of nearly three-quarters of a mile, and a maximum width of about 1,300 feet. The extension northeasterly through W. S. 4, 5, and 6, has a length of nearly 1½ miles and an average width of nearly 900 feet.

The iron formation is made up of finely-banded, cherty iron carbonate rocks, hematitic, magnetitic, and pyritic cherts, and amphibole-magnetite rock, black and red jaspilites and iron ores.

Great variation in the character of the iron formation, both in the direction of strike and across it, is a marked feature of all the belts, yet in a broad way the range may be divided into several areas, each of which is characterized by the relative prominence of one of the various phases of the formation. In general, ferruginous cherts are dominant toward the southwestern end, and the jaspilites are prominent toward the northeast in claims W.S. 4, 5, and 6. The amphibole-magnetite rocks are abundant in claim W.S. 8, while the unaltered iron carbonate rocks have been found only on claim W.S. 6, and in a few places east of Woman river.

Locally, particularly in claims W.S. 11 and 12, iron ores occur. On these claims the ore is low grade, running as high as 43 per cent. in iron in places, with a phosphorus content of about 0.018 per cent. A small amount of sulphur is present as pyrite.

REFERENCE: R. C. Allen, Ontario Bureau of Mines, 1909, pp. 254-262.

Drummond-Dobie Claims.—This group of claims lies about 8 miles southwest of the Leith claims and about 12 miles northeast of Wakami siding on the Canadian Pacific railway. The claims are situated on both sides of Speight's meridian, about 16 miles north of the C.P.R., and lie immediately south of the Ridout river.

On the property there are two main belts of iron formation and a few smaller ones. The main belts strike a little south of east, have lengths of about 3 miles, and lie about half a mile apart.

The northern belt, which has a width of about 200 feet, is composed of interbanded magnetite and silica. While picked specimens of ore running as high as 63 per cent. iron have been secured, assays appear to indicate an average iron content of about 35 per cent. for the range.

The southern belt, the width of which varies from 300 to 900 feet, is reported to consist of massive magnetite. Assays indicate an average iron content probably above 40 per cent. The character of the massive ore is somewhat varied; in some places it is free from sulphides, and in others it is heavily impregnated with pyrite and pyrrhotite (cf. Smith claims p. 201). A series of analyses show the following ranges:—

	Per cent.
Iron	35.62 to 63.50
Silica	4.20 to 48.73
Sulphur	0.04 to 20.15
Phosphorus	0.02 to 0.15
Manganese	0.30 to 0.47
Titanium	Traces.

Messrs. Clemont and Gordon have claims staked adjacent to those just described, but there is no information available concerning their showings.

REFERENCE: Thomas Drummond.

McLaren Claims.—These claims include outcrops of iron formation lying from three to 5 miles southwest of the Drummond-Dobie claims. They lie west of the 16th mile of Speight's meridian, and about 10 miles northeast of Sultan siding on the Canadian Pacific railway.

This iron formation area is conspicuous in that it is at a higher elevation than the surrounding country for many miles in all directions.

The iron formation rocks constitute probably 75 per cent. of the rock areas exposed on the eight claims, and their areal extent is probably more than 25 per cent. of the total area of the claims.

The longest belt of iron formation can be followed from a point a little east of the second portage on Isaiah creek with only one break (of about five claims) for a distance of 1¼ miles southeasterly. The westerly portion is nearly three-quarters of a mile long and varies from 200 to 350 feet in width; the southeasterly portion is nearly half a mile long and has a maximum width of about 600 feet.

The iron formation is composed nearly altogether of cherty and granular silica. The chert is white, grey, and black, and is often mottled with grey spots. The black chert may be mistaken for magnetite. The granular silica is grey, brown, and red in colour. Speaking generally, the iron formation is banded. In some places the bands are broad and conspicuous; at others the banding is not so distinct, the bands tapering to points in very short distances. A few bands of magnetite and a few of pyrite were noticed.

A short distance to the east of the southeast end of the belt just described, there is a hill with an area of 12 acres, which seems to be a solid mass of iron formation, composed of massive cherty and granular silica. One band of magnetite six inches thick was uncovered on this hill.

Immediately to the south of the hill, there is a detached area of iron formation, 75 feet wide and 300 feet long, which is distinctly banded. The whole iron formation bed is only 25 feet thick, and it dips at 35° to the west. Magnetite in clean-cut bands of an inch or more in thickness is exposed plentifully at this outcrop; several bands six inches thick were noticed; also one 1 foot thick, and one 2 feet thick. A representative sample of the magnetite exposed in this area gave the following analysis:—

	Per cent.
Iron	41.78
Silica	25.70
Sulphur	1.47
Phosphorus	0.027

About 1,000 feet to the southeast of the long belt of iron formation first described, there is another belt, the strike of which is at right angles to that of the former. The length of this is 4,000 feet, and the average width is about 325 feet. At its northeast end it almost joins another band striking to the northwest. This is 1,500 feet long and 325 feet wide. Both belts are composed chiefly of granular and cherty silica, both massive and banded. Narrow bands of magnetite are exposed in a few places.

Lying a couple of miles to the southwest is a bare hill 1,000 to 1,200 feet wide and 2,700 feet long, composed solely of iron formation. Except in the northeast corner the iron formation is composed of massive cherty and granular silica. A few very narrow bands of magnetite are exposed.

REFERENCES: L. L. Bolton for Lake Superior Corporation, Sault Ste. Marie, Ont., 1910.
A. A. McLaren, Chapleau, Ont., 1915.

Marks Claims.—About 5 miles north of the McLaren claims and about 3 or 4 miles northwest of the Drummond-Dobie claims, lie the Marks claims which cover an area 4 miles long from east to west, and half a mile wide. They are situated on the north side of the Ridout river, about 15 miles northeast of Ridout station on the Canadian Pacific railway, from which point they may be reached by a six-hour canoe trip.

The surface of the property is rolling and is composed of gravelly and clayey material, through which a few low-lying rocky ridges outcrop occasionally. Almost all the exposures of interest have been made by trenching and stripping.

The two rows of claims are supposed to include two parallel bands of iron formation, each with a length of nearly 4 miles and lying about one-quarter of a mile apart.

Through the north row of claims there is either a narrow band of iron formation or a series of narrow bands lying almost in line with no long breaks between. The cross-trenches have exposed chiefly rusty-weathering schists, probably schists which in their unweathered condition contain varying proportions of carbonates. In addition there are exposed cherts of various colours, granular silica both massive and banded, and impure carbonates. Only one outcrop showed magnetite, and there the magnetite occurred only in scattered grains.

In the southerly row of claims, the three most westerly claims show brown-weathering schists with cherty carbonate layers, occasional outcrops of massive cherty carbonates, and pyritic and sideritic chert. Through the next 11 claims to the east there seems to be a more or less persistent band of rusty-weathering, impure carbonate associated with brown-weathering schists. A typical specimen of the rusty-weathering carbonate gave the following analysis:—

	Per cent.
Iron	4.78
Silica	28.20
Lime	1.00
Magnesia	17.38
Loss on ignition	33.08

This shows it to be an impure dolomite. No outcrops of iron ores were seen.

Reference: L. L. Bolton for Lake Superior Corporation, Sault Ste. Marie, Ont., 1910.

Claims West of Cache Lake.—To the west and southwest of Cache lake and about 8 miles northeast of Ridout station, two groups of iron claims have been staked; the Moore and Clemont group, and the Marks group. These define the most southwesterly limit of the Woman river iron range.

On the Marks claims, there is a fairly persistent band of rusty-weathering schists about a mile in length.

Reference: L. L. Bolton for Lake Superior Corporation, Sault Ste. Marie, Ont., 1910.

GROUNDHOG RIVER AREA

The Canadian National railway transcontinental line near its crossing of the Groundhog river, 150 miles northwest of Sudbury, crosses an iron range striking east and west through the Townships of Keith and Penhorwood. Claims have been staked along this for a distance of about 6 miles.

Algoma Eastern Railway Claims.—These claims lie along both sides of the Groundhog river about half a mile below the Canadian National railway crossing. On them an iron range 75 feet wide and 1,200 feet long has been shown up by trenching. Surface relief shows a vertical extent of at least 75 feet. No sinking or diamond drilling has been done.

Three representative analyses are given below. No. 1 sample was a groove sample across 75 feet of iron formation; No. 2 was across 13 feet; and No. 3 was a picked specimen of the best ore exposed.

	No. 1 per cent.	No. 2 per cent.	No. 3 per cent.
Iron	37.02	40.28	63.07
Silica	45.84	39.29	11.92
Sulphur	None	None	0.18
Phosphorus	0.035	0.062	Trace
Titanium	None	.....	None
Alumina	1.43	.....	.....
Lime	None	.....	.....

The iron range is composed of magnetite and hematite interbanded with jasper and occasionally with iron-magnesia silicates.

A 20-ton sample was sent to the ore dressing plant of the Mines Branch, Ottawa, for concentration tests. The crude ore ran 34.41 per cent. iron. The best results secured from a series of experimental runs, showed only a 60.5 per cent. recovery of the iron content and gave a concentrate running only 49.8 per cent. iron.

References: W. G. Miller, Ontario Bureau of Mines, 1903, p. 315.
J. A. Dresser for Algoma Eastern Railway, 1914.
W. B. Timm, Mines Branch, Summary Report, 1913, pp. 81-88.

SHINING TREE LAKE AREA

Shining Tree lake area lies along the boundary between the districts of Sudbury and Timiskaming, and is about 75 miles due north of Sudbury and about 28 miles northeast of Ruel station on the Canadian Northern railway.

A number of iron range occurrences in the vicinity have attracted attention. Some lie in the district of Sudbury and some in Timiskaming. The former will be described here.

Big Four Locations.—This property consists of mining locations W.D. 480, 481, 482, and 483, situated at Big Four lake in the Township of McMurchy, about seven miles northwest of Shining Tree lake.

Iron formation is reported to extend for a distance of 2,800 feet across the property, with a width varying from 200 to 300 feet. The iron formation consists of chert, white, grey, black, and resinous in appearance; granular silica, red and brown in colour; cherty rocks with white, red, and brown cappings; granular, siliceous iron oxides; red jasper and magnetite; hematite and pyrite; the iron ores being very sparingly present. Distinct banding characterizes only small areas. At one exposure clean magnetite in bands up to $2\frac{1}{2}$ inches in thickness constitutes about one-fifth of the iron formation.

References: L. L. Bolton for Lake Superior Corporation, Sault Ste. Marie, Ont., 1909.
D. B. Rockwell for R. H. Flaherty, Port Arthur, Ont., 1910.
J. F. Black, Sudbury, Ont., 1914.

Mining Location W.D. 479.—This is situated on the south shore of Howston lake in the township of McMurchy, and is about $2\frac{1}{2}$ miles east of the Big Four locations.

On this location there are a few outcrops of red jasper surrounded by Keewatin schists and greenstones. The jasper outcrops do not exceed 40 feet in diameter, and their contacts with the surrounding rocks are irregular and indistinct.

Reference: L. L. Bolton for Lake Superior Corporation, Sault Ste. Marie, Ont., 1909.
D. B. Rockwell for R. H. Flaherty, Port Arthur, Ont., 1910.

Mining Locations W.D. 475, 476, 477, and 478.—These lie along the 62nd and 63rd miles of the Sudbury-Timiskaming district line, about two miles north of Shining Tree lake. They include an iron formation band which can be traced for some distance to each side of the district line.

To the northwest the iron formation stretches for a mile with a maximum width of 100 yards. It is composed of jasper (not very bright red in colour) and chert, usually greyish-black, both more or less interbanded with magnetite. Pyrite occurs not infrequently in the chert. At some points the iron formation has a brown capping.

To the southeast in the District of Timiskaming the range can be picked up at frequent intervals for $3\frac{1}{2}$ miles. This portion of the range is composed chiefly of jasper, often bright red. At some points the jasper is interbanded with purplish magnetite. No ore of value was seen.

References: E. M. Burwash, Ontario Bureau of Mines, 1896, p. 174.
A. P. Coleman, Ontario Bureau of Mines, 1901, p. 183.
L. L. Bolton for Lake Superior Corporation, Sault Ste. Marie, Ont., 1909.
D. B. Rockwell for R. H. Flaherty, Port Arthur, Ont., 1910.

ONAPING LAKE AREA

About 3 miles east of the north end of Onaping lake, and between it and Meteor lake, red jasper associated with magnetite is found on a long ridge. The ridge strikes northwest and southeast.

Reference: A. P. Coleman, Ontario Bureau of Mines, 1901, p. 187.

A report on the property of the Onaping Iron Company near Onaping lake, says that there are areas of banded iron formation with occasional pockets of ore averaging from 35 to 50 per cent. iron. Considerable test-pitting, trenching, and stripping has been done.

Reference: H. E. Knobel for D. D. Mann, Toronto, Ont., 1909.

BURWASH LAKE AREA

Near Burwash lake, 16 miles north of Moose Mountain mine, there are numerous outcrops of iron formation composed of interbanded silica, magnetite, and green hornblende, and entirely enclosed by intrusive granite-gneiss. The richest formation contains probably less than 30 per cent. iron. The larger deposits after exploration by diamond drilling were abandoned.

Reference: W. H. Collins, Geological Survey of Canada, Summary Report, 1912, p. 311.

ROBERTS AND BOTHA TOWNSHIPS

On lots 3 and 4, concession IV, Roberts township, there are two prominent iron formation outcrops besides several minor ones.

The westerly exposure shows a section of banded granular silica and magnetite about 15 feet thick dipping to the west at only a few degrees from the horizontal.

The other outcrop lies a quarter of a mile east of the one just described. This shows a flat-lying bed of banded granular silica and magnetite dipping at a low angle to the west. The thickness of the bed probably does not exceed 20 feet.

The average iron content of the iron formation outcrops is probably between 30 and 35 per cent.

REFERENCES: L. L. Bolton for Lake Superior Corporation, Sault Ste. Marie, Ont., 1909.
D. B. Rockwell for R. H. Flaherty, Port Arthur, Ont., 1910.

Near Morin lake in Roberts township, two iron formation bands are reported. The band in location W.R. 121 is about 150 feet wide and 1,400 feet long. The iron formation consists of alternating bands of silica and magnetite, and would probably average less than 30 per cent. iron. The outcrop on W.R. 108 shows a small area of banded iron ore and silica lying nearly flat, with slight dip to the northwest. The total thickness is from 12 to 15 feet. This iron formation appears to have a very low iron content.

Stretching westward from McCrindle lake, which lies on the west boundary of Roberts township, there is a belt of lean banded iron formation extending to and beyond Roam and Sandfly lakes, a distance in all of nearly 7 miles. This lies wholly in Botha township.

REFERENCE: M. T. Culbert, Ontario Bureau of Mines, 1904, part 1, pp. 222-224.

MOOSE MOUNTAIN AREA

The expression Moose Mountain area is here applied to an area of some four square miles extending northwesterly from lot 6, concession III, of Hutton township, into the adjoining township of Kitchener, a distance of 4½ miles. It includes the ore bodies known as Moose Mountain mine, located at the village of Sellwood on the Canadian National railway, and many undeveloped iron formation bands, the whole group being sometimes referred to as the Hutton township iron range.

In the Moose Mountain area 11 deposits of all grades have been delimited by surface exploration and magnetometric surveys. The iron ores of the area may be divided into two types.

Type A: Those in which magnetite is found in irregular masses, associated with pyroxene, hornblende, and epidote.

Type B: Those consisting chiefly of fine-grained siliceous magnetite, interbanded with siliceous material including chert and phases resembling quartzite.

To type B may be assigned all the deposits except Nos. 1 and 5. The following is the analysis of an average sample across No. 2 deposit, and it is probably fairly representative of the deposits of type B:—

	Per cent.
Iron	36.70
Silica	45.20
Sulphur	0.024
Alumina	0.250
Lime	1.06
Magnesia	1.59
Manganese	0.04

The exceedingly fine texture and the intimate association of magnetite with the silica render it impossible to obtain a marketable product from this type of ore by a simple cobbing process, and it is only by a very fine grinding of the material that a satisfactory separation of the magnetite from the silica can be obtained.

Deposits Nos. 1 and 5 belong to type A described above. These two deposits are comparatively small their aggregate area being only 71,000 square feet. So far the principal mining operations have been confined to these deposits. The horizontal area of No. 1 deposit is 47,000 square feet, most of which has already been opened up. By diamond drilling, the ore body has been proved to a depth of 300 feet below its highest outcropping.

Mining operations at No. 1 deposit have demonstrated that the magnetite, hornblende, and epidote often show a more or less pronounced segregation into irregular layers and lenses. For this reason it is almost impossible to give any figures which may be said to represent the average iron content of this type of ore. Some parts of the ore body average 60 to 65 per cent. iron, while others, often in the immediate vicinity, consist of hornblende or epidote; and between these two extremes all gradations exist. The following analysis gives the average composition of the 1914 shipments of concentrates crushed to pass one-inch ring and screened on an 8-mesh screen:—

	Per cent.
Iron	54.45
Silica	14.55
Sulphur	0.036
Phosphorus	0.105
Alumina	2.09
Lime	4.00
Magnesia	2.83
Manganese	0.07
Loss by ignition	0.75

The total area of the various deposits is roughly estimated as 3,256,000 square feet, of which 3,185,000 square feet is the area of the low-grade deposits of type B. Assuming that the average specific gravity of the ore is 3.8, there should be 38,665,000 tons of siliceous ore for every 100 feet in depth of the ore bodies. A large amount of experimental work on these ores has been carried on, and a high-grade product made.

REFERENCES: C. K. Leith, Ontario Bureau of Mines, 1903, pp. 318-321.
A. P. Coleman, Ontario Bureau of Mines, 1904, pp. 216-221.
E. Lindeman, Moose Mountain Iron Bearing District, 1914, Mines Branch, Ottawa, No. 303.
F. A. Jordan, c/o Moose Mountain, Limited, Sellwood, Ont., 1914.

Moose Mountain Mine.—For detailed description, see page 161.

WISNER AND BOWELL TOWNSHIPS

Clear lake lies in lots 9, 10, and 11, concession VI of Wisner township, about 4 miles southwest of Sellwood village on the Canadian Northern railway. A short distance to the south of this lake several outcrops of interbanded quartzitic silica and magnetite have been located. The greatest width of any outcrop seen was 24 feet, and the bands were nowhere traceable for much more than 100 feet. As ore deposits they are of no importance, the proportion of magnetite being too small; and the presence of pyrite still further lowers the quality.

Similar bands of iron formation are found a few miles west of Clear lake in *lots 1 and 2 of concessions V and VI of Bowell township.* Some of these were explored by diamond drill in 1908 and 1909 with unfavourable results.

REFERENCES: A. P. Coleman, Ontario Bureau of Mines, 1901, pp. 185-186.
L. L. Bolton for Lake Superior Corporation, Sault Ste. Marie, Ont., 1902.

WANAPITEI LAKE AREA

At the northwest of Wanapitei lake, iron formation outcrops have been located on different lots in Rathbun, Norman, and Parkin townships. This iron-bearing area lies about 10 miles southeast of Moose Mountain mine at Sellwood, and about 6 miles east of Norman station on the Canadian Northern railway.

In *Rathbun township* iron formation outcrops occur in lots 22, 23, and 24, concession VI.

One group of outcrops lies near the east side of lot 22 not far from the shore of Wanapitei lake. The iron formation is composed principally of quartzitic silica interbanded with siliceous magnetite. It also includes areas of reddish jasper interbanded with both lustrous steely-looking magnetite, and dark-coloured hematite. A few bands of ore 4 or 5 inches wide and 2 to 3 feet long were observed.

To the northwest of this on a high hill in lot 24 lies the largest exposure of iron formation. This varies in width from 125 to 600 feet, and has a length of 1,500 feet. The iron formation consists of cherty and granular silica interbanded with magnetite. Generally speaking the magnetite bands are sparingly present. Their thickness rarely exceeds 2 inches and is usually very much less.

On several of the smaller exposures between the two groups described, there is a rusty capping due to oxidation of sulphides occurring in the silica.

Several diamond-drill holes were put down on the principal exposures in 1908 and 1909, but so far as could be learned the proportion and mode of occurrence of silica and magnetite at depth is identical with that on surface.

No portion of any of the iron formation outcrops seen would make a merchantable ore.

On *lots 3 and 4, concession VI in Norman township* (a mile or more west of the Rathbun township outcrops), there are numerous outcrops of very siliceous banded iron formation. The iron mineral is magnetite, and the maximum thickness of the magnetite bands is one inch. A little pyrite is disseminated through the silica. The size and mode of occurrence of the outcrops suggest the presence of a number of isolated deposits of iron formation rather than one or more of good size.

On *lot 3, concession I in Parkin township*, immediately to the north of the Norman township outcrops, there are a few natural outcrops of iron formation of similar character to those in Norman. As this lot was heavily wooded, the outcrops are small and no connection between them

could be established. One small rock face 8 feet long and 2 to 4 feet high shows magnetite of good quality like the better portions of the Moose Mountain deposit.

REFERENCES: W. G. Miller, Ontario Bureau of Mines, 1901, p. 177.
M. T. Culbert, Ontario Bureau of Mines, 1904, p. 224.
L. L. Bolton for Lake Superior Corporation, Sault Ste. Marie, Ont., 1909.
D. B. Rockwell for R. H. Flaherty, Port Arthur, Ont., 1910.

CARTIER AREA

The *Geneva Lake property* consists of some claims along the south boundary of the township of Munster, about 4 miles north of Geneva lake and 5 to 6 miles north of the Canadian Pacific railway main line.

The ridge on which the workings are located, consists of a soft, dark-green chloritic rock which contains inclusions of light greenish to white, sometimes banded, quartzose material. There are irregular patches of segregations of crystallized magnetite with chlorite scattered through the greenstone. Chlorite and magnetite are also associated with the quartzose inclusions and contained in them. Occasionally intermixed with the magnetite there is some hematite. A rock excavation shows one band of ore 8 feet wide, but the extent of this deposit lengthwise and vertically has not been demonstrated. Diamond drilling in 1909 failed to reveal any ore.

REFERENCES: L. L. Bolton for Lake Superior Corporation, Sault Ste. Marie, Ont., 1909.
D. B. Rockwell for R. H. Flaherty, Port Arthur, Ont., 1910.

Gaudaur Iron Claim.—Near the southeast of Ulster township, and about 3 miles north of the Canadian Pacific railway, is located the Gaudaur iron claim. Here in a slaty greywacké, there are exposed several narrow bands of low-grade siliceous iron formation. The total width across which such bands are exposed is 75 feet. The bands are of too low iron content, and are too small to offer any attraction as an iron prospect.

REFERENCE: L. L. Bolton for Lake Superior Corporation, Sault Ste. Marie, Ont., 1908.

Whissell Claims.—The Whissell claims are located in Moncrieff township, and lie along both sides of the Canadian Pacific railway, about 10 miles west of Cartier village. On them there are exposed several bands of granular silica, through which there is disseminated pyrite and pyrrhotite. The bands are narrow and short. They all have a rusty capping due to the oxidation of contained sulphides. As iron ore prospects these are of no interest.

REFERENCE: L. L. Bolton for Lake Superior Corporation, Sault Ste. Marie, Ont., 1912.
H. Bradley for R. H. Flaherty, 1912.

Moore and Johns Claims.—The Moore and Johns claims lie in lots 6 and 7, concessions I and II, Hart township, about 7 miles southwest of the village of Cartier. On them there are several belts of banded iron formation, one of which has a width of 200 feet. The iron formation is composed mainly of interbanded chert of various colours. In some places there are magnetite bands, and occasionally the magnetite is of high grade; but magnetite comprises an insignificant proportion of the iron formation.

REFERENCE: Albert Scott for Lake Superior Corporation, Sault Ste. Marie, Ont., 1909.

Groves Claims.—These claims are located in lot 7, concession III of Hart township, and are about 6 miles southwest of Cartier.

A considerable amount of stripping has revealed many pockets of magnetite, some of which is of fair quality. The small size of the pockets and the limited extent of the ore-bearing areas give no promise of any tonnage of interest of marketable ore.

REFERENCES: L. L. Bolton for Lake Superior Corporation, Sault Ste. Marie, Ont., 1910.
H. Bradley for R. H. Flaherty, Port Arthur, Ont., 1912.

WHITEFISH RIVER AREA

The *Wallace Mine location* is located on the north shore of Lake Huron just west of the mouth of the Whitefish river and about 10 miles north of the town of Little Current.

In the northwest corner of the location, a vein of hematite occurs in quartzite. The vein, where a pit has been sunk in it, has a width of 8 feet, but it contains some inclusions of rock. The ore vein may be traced by natural outcrops 200 to 300 yards westward, but it is only 2 feet wide where last visible.

REFERENCES: Royal Commission on Mineral Resources of Ontario, 1890, p. 123.
G. L. Michael for Lake Superior Corporation, Sault Ste. Marie, Ont., 1909.

On the Whitefish Indian Reserve (just east of the Wallace Mine location), 207 feet of diamond drilling was done on an iron prospect in 1903. The only indications of iron met with appear to have consisted of fragments of ore in drift boulders and an occasional softer band of the quartzose rock impregnated with hematite.

REFERENCE: Ontario Bureau of Mines, 1904, p. 43.

8. District of Timiskaming

MATTAGAMI RIVER AREA

At *Grand Rapids on the Mattagami river*, about 80 miles north of the National Transcontinental railway, limonite deposits of considerable size are found in Devonian limestone.

On the northwest side of the river, at the foot of the rapids, there is an outcrop of limonite, with an exposed breadth of 20 to 25 feet, running along the foot of a cliff almost continuously for a distance of upwards of 300 yards. The highest points rise about 15 feet above the level of the river. The ore is believed to be an oxidation product of siderite, associated with the limestone at the head of the rapids, where similar deposits of limonite occur in two places. These extend across the bed of the river and stretch along the shore for about 1,100 feet in each case. They reach in places 15 to 18 feet above the level of the river, but their full thickness cannot be estimated, as they extend below water level in almost every case. Nor could it be ascertained how far they extend inland from the banks of the river.

In places the ore is a soft, often botryoidal, vuggy limonite in radiating, lumpy masses. At other places it is a dense, hard hematite or compact limonite. Again it passes into coarse conglomerate, composed of small water-worn pebbles of quartz in a matrix of clay and limonite. The deposits are, therefore, of a very mixed character, in some places the material being high enough to constitute a fair ore, while in others it is quite low in iron content. Analyses of representative samples of the ores exposed are given herewith.

	No. 1 per cent.	No. 2 per cent.	No. 3 per cent.	No. 4 per cent.	No 5. per cent.
Iron	52.45	52.10	41.68	37.35	36.68
Sulphur	0.14	0.11	0.15	0.16	0.60
Phosphorus	0.08	0.14	0.12	0.13	0.09
Moisture	1.16	0.94	1.70	1.56	1.42

Sample No. 1—Average of the best ore at the foot of the rapids on the north side.
Sample No. 2—Best ore below high-water mark at the foot of the rapids on the north side.
Sample No. 3—Average ore from the foot of the rapids, south side.
Sample No. 4—Average of the best ore at the head of the rapids, south side.
Sample No. 5—Average of 850 feet of exposure at the head of the rapids, south side.

The siderite from which the iron oxides are supposed to have been formed, is of exceptionally high grade, as is shown by the following analysis:—

	Per cent.
Iron	42.37
Silica	1.40
Sulphur	None
Alumina	2.31
Lime	1.47
Magnesia	Trace
Manganese oxide	1.74
Carbon dioxide	34.94

The Mattagami River siderite deposits were examined in 1919 by J. G. Cross, who during that year was on reconnaissance survey for the Ontario Department of Mines in the area between Cochrane and Moose Factory. In his report he describes the siderite outcrops and presents analyses of several samples. Siderite occurs at both the head and foot of the rapids, but only the former is of good quality. A sample of this siderite has the following composition:—

	Per cent.
Iron	43.52
Silica	5.40
Alumina	2.63
Sulphur	0.74
Phosphorus	0.08
Manganese	nil
Water	2.18
Carbon dioxide	30.40

The chief impurities in the ore are silica, clay, limestone, sulphur, and organic matter. Silica in the form of sand and gravel was often observed in the inferior grades. The clay content is also very high in places. Limestone is also present, often in the form of a breccia with siderite as the cement. Sulphur occurs as pyrite of which occasional specks can be seen. The organic matter is probably lignite.

The main ore body has a maximum width of about 600 feet. The lateral extension could not be determined, as the body is hidden on the south by glacial debris. On the north it is

exposed in the bottom of the river for about 600 feet; but the extension is hidden by the water and boulders. A very small outcrop on the north bank indicates that the ore extends across the river bottom.

The ore-bearing zones at the foot and head of Grand Rapids have a trend a little west of north (magnetic) and are separated by about a mile of barren limestone. The sediments appear to form a very gentle anticline; the dip is scarcely noticeable. The age of the siderites is probably Cretaceous.

REFERENCES: J. M. Bell, Ontario Bureau of Mines, 1904, pp. 152-156.
M. B. Baker, Ontario Bureau of Mines, 1911, pp. 238-246.
J. G. Cross, Ontario Bureau of Mines, 1920, Vol. XIX, pt. 2, pp. 9-16.

OPASATIKA RIVER AREA

Near *Breakneck falls on the Opasatika river*, about 25 miles above the mouth of the river and about 40 miles north of the National Transcontinental railway, there are numerous outcrops of iron-bearing rocks. The varieties noted are poorly ferruginous magnesian limestone, richly ferruginous magnesian limestone, siderite, and siliceous limonite or goethite and hematite. The rock is usually coloured a deep ochre, or dark red, and in texture is as a whole soft, dense and, fine-grained, containing numerous geodes of quartz crystals and veinlets of specular hematite. It is sometimes botryoidal and even stalagmitic. The rock is never sufficiently rich in iron to be graded as an iron ore. The following analyses represent chemically the character of the iron-bearing rocks:—

	Siliceous hematite	Ferruginous limestone	Siderite
	per cent.	per cent.	per cent.
Iron	24.39	3.09	43.47
Silica	53.14	1.00	......
Sulphur	0.15	.....	......
Phosphorus	0.028	.....	......
Alumina	1.10	0.56	......
Lime	1.95	29.36	......
Magnesia	1.14	19.56	......
Manganese dioxide	0.66	.....	......
Loss on ignition	6.40	44.40	37.90

It is impossible to make any accurate estimate of the extent of the iron-bearing rocks as they lie horizontally and are exposed only on the river banks, but the total volume is undoubtedly large.

REFERENCE: J. M. Bell, Ontario Bureau of Mines, 1904, p. 150.

ABITIBI AREA

About the middle of the west shore of *Lower Lake Abitibi, on Island No. 14*, and on the mainland immediately north of that, are two outcrops of jaspilite iron formation. The dip of the formation is practically vertical and the strike is 23 degrees north of east. The iron formation consists of alternate bands of magnetite and silica. The width of the outcrops is 60 feet, but the length of the deposit could not be determined owing to a heavy covering of soil.

REFERENCE: M. B. Baker, Ontario Bureau of Mines, 1909, p. 276.

MUNRO AND WARDEN TOWNSHIPS

On *lot 10, concession II*, and other parts of Munro township, exposures of iron formation, consisting of narrow, alternating bands of sugary quartz and magnetite and dipping vertically, are enclosed in the greenstones.

On *lot 10, concession I*, of Warden township, the white-weathering serpentine contains a network of numerous veinlets of magnetite which withstand weathering and project above the serpentine.

REFERENCE: P. E. Hopkins, Ontario Bureau of Mines, 1915, p. 176.

PORCUPINE AREA

Whitney Township.—Banded iron formation outcrops frequently in the southwest part of Whitney township in concessions I and II. The bands are alternate reddish, or greyish quartz, and magnetite and hematite. Sometimes the narrow bands of magnetite, one-eighth of an inch thick, carry a merchantable percentage of iron, but these are relatively subordinate in comparison with the main mass of rock. It is unlikely that merchantable ore will be found in quantity.

REFERENCE: A. G. Burrows, Ontario Bureau of Mines, 1912, p. 213.

Deloro and Shaw Townships.—In Deloro and Shaw townships bands of banded iron formation can be traced for several miles in a direction a little south of west. Often the formation carries no iron ores, with the result that it greatly resembles a wide quartz vein. Bands of carbonate rocks are closely associated with the iron formation for a distance of several miles.

REFERENCE: A. G. Burrows, Ontario Bureau of Mines, 1912, pp. 213-214.

McArthur Township.—Iron formation bands are found among the Keewatin rocks in the southeast quarter of McArthur township. The largest body of iron formation is on a trail about one mile east of *Triple lake.* It consists of banded silica and magnetite, some bands of which are an inch in width.

REFERENCE: P. E. Hopkins, Ontario Bureau of Mines, 1912, p. 278.

MONTREAL RIVER, EAST BRANCH

Yarrow Township

Bradshaw Claims (H.E. 70 and 71).—These claims lie on the west side of Neat lake, an expansion of the East Branch of the Montreal river. An iron-bearing quartz vein apparently stretches continuously across them. The vein strikes east and west, dips south at 80 degrees, and has a maximum exposed width of 6 feet. In this vein hematite is present in sufficient quantity to attract attention, although no large pockets of ore are exposed. There are also large areas of quartz exposed which show no ore. The hematite is occasionally of good quality, but is generally quite siliceous.

REFERENCE: L. L. Bolton for Lake Superior Corporation, Sault Ste. Marie, Ont., 1909.

Ferguson Claims (J.S. 65 and 66).—These claims are located at the foot of Neat lake, about 2 miles north of the Bradshaw claims. On J.S. 66, a few strippings on a quartz vein have exposed two spectacular-looking pockets of radiating botryoidal hematite of high grade. One pocket is 20 feet long and from 1 to 2 feet wide, and the other is 10 feet long and 3½ feet wide. There is no prospect of any tonnage of interest being proven.

REFERENCE: L. L. Bolton for Lake Superior Corporation, Sault Ste. Marie, Ont., 1909.

SHINING TREE LAKE AREA

In the southwestern quarter of *Tyrrell township* unimportant outcrops of iron formation are found for a distance of 3½ miles, the iron formation being composed chiefly of jasper, often bright red, which at some points is interbanded with purplish magnetite. This is an extension of the range in mining locations W.D. 475, 476, 477, and 478, described among the Sudbury district iron ore occurrences.

REFERENCES: A. P. Coleman, Ontario Bureau of Mines, 1901, p. 183.
W. H. Collins, Geological Survey of Canada, Summary Report, 1910, p. 201.

Near *Wapoose lake in Leonard township* a number of claims have been staked on a group of deposits of fine-grained magnetite. With the magnetite are associated banded silica rocks, jasper, and siderite. The principal ore body outcrops along the apex of a ridge with strike approximately north and south, and it has been cross-cut by trenches at intervals of 40 feet for a distance of 1,900 feet. The ore body maintains a fairly uniform thickness of about 40 feet, and dips towards the west at an angle of about 78 degrees.

The principal ore outcrops were systematically sampled. The surface exploration and sampling indicate that there is undoubtedly a large tonnage of ore of the following average analysis:

		Per cent.
Iron		40.63
Silica		15.43
Sulphur		2.71
Phosphorus		0.014
Lime	about	7.5
Magnesia	"	4.0
Manganese	"	2.25

References: G. R. McLaren for Lake Superior Corporation, Sault Ste. Marie, Ont., 1910.
W. H. Collins, Geological Survey of Canada, Summary Report, 1910, p. 201.
R. H. Flaherty, Port Arthur, Ont., 1911.

Mining Claims N.R. 3412 and 3414 are located about 1 mile northwest of the Wapoose Lake claims. The iron formation here consists of a band of chert agglomerate which is composed of elongated fragments of dark grey chert in a dark green felsitic matrix. An area of banded red jasper and brownish-grey chert lies next the agglomerate. Nothing of value has been shown on the property.

Reference: D. B. Rockwell for R. H. Flaherty, Port Arthur, Ont., 1910.

BOSTON AND OTTO TOWNSHIPS

About half a mile east of Dane station on the Timiskaming and Northern Ontario railway the *Boston Township iron range* is picked up, and from there it extends east and northeast almost to the northeast corner of Boston township, having a length of about 7 miles.

The iron formation consists of magnetite interbanded with jasper and other closely related siliceous material. The range has been subjected to considerable disturbance by intrusions of igneous rocks. The width is not usually more than 90 to 100 feet, and the maximum width observed was 300 feet.

Reference: W. G. Miller, Ontario Bureau of Mines, 1905, p. 262.

In *Otto township* westward from Dane station, banded iron formation composed of alternate bands of magnetite and silica, occurs at several points along the south edge of the Keewatin belt.

Reference: E. L. Bruce, Ontario Bureau of Mines, 1912, p. 256.

ENGLEHART AREA

In *lots 1 and 2, concession V, Dack township* (about 2 miles west of Englehart station on the Timiskaming and Northern Ontario railway), two claims have been staked for iron. The country rock is greenstone. The iron prospect consists of a faulted zone with a maximum width of a few inches which has been filled with a mixture of calcite, lean, reddish iron oxides, and hematite. The reddish oxides ramify back for a couple of feet from the fault zone as stringers and films in cracks in the greenstone. The property is valueless as an iron prospect.

References: D. B. Rockwell for R. H. Flaherty, Port Arthur, Ont., 1910.
L. L. Bolton for Lake Superior Corporation, Sault Ste. Marie, Ont., 1910.

On *lot 9, concession VI, Bayly township* (about 10 miles northeast of Englehart), a few claims have been staked for iron. The country rock, which is badly weathered, is greyish in colour, and in part is schistose; possibly it was originally a greenstone. In the schistose portions of the rock particularly, there has been extensive deposition of silica. The silica deposits are irregular in outline, and the greatest observed dimension of any one deposit was 100 feet. The silica is chiefly flinty in texture and it varies from white to bluish-grey in colour; a small proportion is of sugary texture, and is brown and red in colour. A little calcite is scattered irregularly through the silica. In places in the silica deposits magnetite occurs in reticulating veinlets not often over a few feet in length and with a maximum width of 4 inches. The magnetite appears to be of good quality. Associated with the magnetite there is quite a little pyrite in veinlets and irregularly shaped pockets. The property is of no interest as an iron prospect.

Reference: L. L. Bolton for Lake Superior Corporation, Sault Ste. Marie, Ont., 1909.

LATCHFORD AREA

On *Mountain lake*, 6 miles south of Latchford on the Timiskaming and Northern Ontario railway, a group of claims has been staked on showings of titaniferous magnetite.

The country rocks on these claims are all of basic composition, with gabbro and greenstone occurring most plentifully. The deposits of titaniferous ore appear at random through these basic rocks, and apparently are segregations from them, for the ore deposits show all gradations from clean ore to rock. The ore outcrops are generally small, the longest continuous outcrop measuring 45 feet; ordinarily, the widths of the ore bands are less than 15 feet. No indications were noticed which suggest a segregation of merchantable ore of economic interest.

Reference: L. L. Bolton for Lake Superior Corporation, Sault Ste. Marie, Ont., 1910.

9. District of Nipissing

TIMAGAMI LAKE AREA

Adjacent to the northeast arm of Lake Timagami there are three iron ranges on which detailed geological work and a considerable amount of exploration work have been done. They are the *Northeast Arm range*, the *Vermilion range*, and the *Ko-ko-ko range.*

The iron formation in all these ranges consists of siliceous magnetite, interbanded with variously-coloured jasper and chert. In some instances a small proportion of hematite is present, but this seldom exceeds 25 per cent. of the whole. Some of the richer ore bands contain as high as 55 per cent. iron, but these are exceptions. The association of the magnetite and silica is extremely intimate, and even the richest bands of ore have a high silica content.

The *Northeast Arm range* has received the most attention and study. It is situated north of the northeast arm of Lake Timagami, its eastern end being only about half a mile from Timagami station on the Timiskaming and Northern Ontario railway. It starts about one-tenth of a mile west of the north end of Crooked or Snake Island lake, and passing beneath the waters of Turtle lake, ends in a swamp about 14 chains from Tetapaga creek, having a total length of nearly 5¼ miles, with a width varying from 200 to 500 feet.

The iron formation consists of siliceous magnetite, interbanded with variously-coloured jasper and chert. The surrounding rocks are sericite and chlorite schists. The general strike of the formation is about N. 65°E., with a steep dip towards the north.

The following analyses represent average samples taken at various points along the range:—

ANALYSES OF IRON ORE SAMPLES FROM NORTHEAST ARM RANGE

Sample	Iron	Insoluble	Notes
	per cent.	per cent.	
I	21.3	68.7	Width of outcrop 40 feet
II	24.5	64.2	" " 30 "
III	22.6	66.2	" " 35 "
IV	27.2	59.8	" " 100 "
V	18.6	72.4	" " 25 "
VI	21.7	66.9	" " 45 "
VII	24.2	63.4	" " 32 "
VIII	23.2	66.0	" " 18 "
IX	23.6	63.3	" " 32 "
X	25.9	59.3	" " 36 " T. B. Mine
Average	23.3	65.02	

Some diamond drilling was done on this range in 1904 and 1905, but apparently no deposits of ore of merchantable grade were located.

Concentration experiments were made for the Ontario Bureau of Mines on a small shipment of the better class of material from this range, but the results do not seem to have been conclusive.

REFERENCES: W. G. Miller, Ontario Bureau of Mines, 1901, p. 167.
A. E. Barlow, Geological Survey of Canada, Vol. XV, pp. 120-133AA.
Ontario Bureau of Mines, 1905, pp. 31 and 78A; 1906, p. 26A.
Geological Survey of Canada, Map No. 944, 1907.
Geo. C. McKenzie, Ontario Bureau of Mines, 1908, pp. 272-273.
E. Lindeman, Mines Branch, Summary Report, 1909, p. 67.

The *Vermilion range* lies about one mile north of the westerly half of the Northeast Arm range. It commences a little to the east of Vermilion lake and runs in a southwesterly direction for about 3 miles to the west of Iron lake. To the northeast it is interrupted by a mass of greenstone, while the western end passes beneath the drift. It cannot extend much farther in this direction, as a tongue of granite comes in a short distance west of this lake. The widest portion, just south of Iron lake, measures over 1,000 feet.

The character of the iron formation is similar to that of the Northeast Arm range.

REFERENCES: W. G. Miller, Ontario Bureau of Mines, 1901, pp. 169-171.
A. E. Barlow, Geological Survey of Canada, 1902-3, p. 126AA.
Geological Survey of Canada, Map No. 944, 1907.

The *Ko-ko-ko range* stretches 1¾ miles easterly from Ko-ko-ko lake to within 3 miles of the westerly end of the Vermilion range. This range is famous for the brilliancy of colour of the associated jaspers.

REFERENCES: W. G. Miller, Ontario Bureau of Mines, 1901, pp. 171-172.
A. E. Barlow, Geological Survey of Canada, 1902-3, p. 126AA.
Geological Survey of Canada, Map No. 944, 1907.

Matagama point lies 12 miles southwest of Timagami station and is on the north side of the entrance to the northeast arm of Lake Timagami. Near the shore about a mile northeast of this point, there are some large angular blocks of a dark chloritic rock with magnetite mixed through the mass in considerable proportion. Inland, some distance west of this, are openings which were made about 1898 in a deposit consisting of magnetite and pyrite in a chloritic ground mass. From the openings the band was traced westward to a little bay which lies a short distance north of the house at the outermost part of Matagama point.

About a mile southwest of this house, there is an outcrop of magnetite on the east side of *Timagami island* on which a little stripping has been done. Some large pieces of fairly pure magnetite were obtained here. The ore is coarse in grain and unlike that associated with the jasper in this area. The outcrop on the island seems to be a continuation of the band which runs out on Matagama point. An analysis of a sample of the magnetite from the island showed it to have the following composition:—

	Per cent.
Iron	65.82
Silica	3.60
Sulphur	0.096
Phosphorus	0.04
Manganese	Trace
Titanium	None

REFERENCE: W. G. Miller, Ontario Bureau of Mines, 1901, pp. 168-169.

Austin Bay Iron Range.—At the head of Austin bay which forms the southern extremity of the south arm of Lake Timagami, there is a range of banded iron formation.

The most accessible outcrop lies close to the water's edge, somewhat east and south of the most western point of the bay. It shows on the northern face and on the top of a prominent hill which can be seen for some distance out in the lake.

The belt of iron formation on the hill is composed of thin bands of magnetite interlaminated with white and dark-coloured chert. It has a width of about 375 feet, and its strike is about west or slightly north of west, with a dip of 50 degrees northward. Going across the strike of the belt the needle dips strongly at three different points from 25 to 50 yards apart. Between these points the dip is slight, showing that certain parts of the belt are higher in magnetite than others. A short distance to the westward the belt is broken by the western extremity of the bay. West of this the jaspilite rises into hills of considerable height. In parts of the belt here the magnetite is not abundant, and the dip of the needle is accordingly weak. This iron range has been traced westward with breaks at various points to some islands in the southwest arm of Lake Timagami, and in a southeastward direction from the head of Austin bay to a point near the southern end of Cross lake, being interrupted in places by intrusions of gabbro.

REFERENCE: W. G. Miller, Ontario Bureau of Mines, 1901, pp. 174-175.

Emerald lake lies a few miles west of the southwest arm of Lake Timagami, and can be reached by way of a series of portages leading from this lake into Gull and other lakes. Banded iron formation is found along the eastern shore about half way up the lake. The band is of considerable width and has been traced some distance back from the shore. The jaspilite strikes the shore of the lake at a point just south of which there is a deep bay stretching to the east. Not far south of this point is the largest island in the lake, which rises to a considerable height. Jaspilite outcrops in the northwest corner and runs inland. The magnetite here forms a high percentage of the rock and is quite massive. A pyritic band lies on each side of the jaspilite.

No outcrops of iron formation were found on the western shore of the lake.

REFERENCE: W. G. Miller, Ontario Bureau of Mines, 1901, p. 175.

Huron Mountain Property.—The Huron Mountain iron ore deposits are situated on the northwest shore of Manitopeepagee lake, which is approximately 35 miles southwest of Timagami station and about 6 miles west of the southwest arm of Lake Timagami.

The iron ore occurrences are almost entirely confined to a hill 1,800 feet long and 700 feet wide. The magnetite occurs in the Keewatin iron formation, massive exposures of which flank both sides of the hill. Calcite and garnet are the most common accessory minerals associated with the iron ore. Calcite is also found in patches on both of the exposed ledges of the Keewatin formation. The segregations of ore appear to be of rather narrow width, and those of ore of good grade are few, and, generally speaking, the magnetite is mixed with calcite and rock. Analyses of 40 samples from surface exposures showed the following range in chemical composition:—

	Per cent.
Iron	21.82 to 67.65
Silica	4.71 to 16.16
Sulphur	None to 0.54
Phosphorus	None to 0.002
Alumina	0.4 to 0.21
Lime	5.30 to 8.00
Manganese	0.20 to 0.33

The results of a magnetometric survey indicated that the ore deposits were very shallow, and diamond drilling done in 1908 and 1909 confirmed this supposition.

REFERENCES: J. L. Coulson for Lake Superior Corporation, Sault Ste. Marie, Ont., 1908.
B. F. Haanel, Mines Branch, Summary Report, 1908, p. 53.
F. G. Wait, Analyses of Ores and Minerals, Mines Branch, Ottawa, 1909, p. 59.
R. H. Flaherty, Port Arthur, Ont., 1909.

OLRIG TOWNSHIP

On *lots 7 and 8, concession A* (north of Rutherglen village), there is a belt of crystalline limestone, portions of which are impregnated with hematite. The hematite is present in much too small a proportion to make a marketable iron ore.

REFERENCES: G. R. McLaren, for Lake Superior Corporation, Sault Ste. Marie, Ont., 1910.

At another locality in Olrig township, *W. C. Offer* has staked claims on a belt of crystalline limestone, portions of which are heavily impregnated with magnetite. The portions richest in magnetite are considered too low grade to be workable.

REFERENCE: W. C. Offer, South Porcupine, Ont., 1914.

LAKE NIPISSING AREA

On *Iron island*, about 25 miles west of North Bay, a little exploration has been done for iron. Crystalline limestone outcrops plentifully on the island, and in the limestone about half a dozen little pockets of hematite were observed, one of which measured 18 inches in its greatest horizontal dimension. The exceptional purity of the hematite in these pockets is probably the only reason that attention has been so often directed to them.

REFERENCES: L. L. Bolton for Lake Superior Corporation, Sault Ste. Marie, Ont., 1909.
A. E. Barlow, Geological Survey of Canada, Vol. X, 1897, pp. 150-151.

In *lots 7 and 8, concession IV, of Macpherson township*, a few claims have been staked for iron. There is no distinct body of ore, or even of rocks which characterize iron formations. A band of rock containing iron-bearing minerals, about 25 feet wide and at least 200 feet long, contains a few nodules of siliceous magnetite. Altogether the quantity is insignificant, and the walls on both sides are granite, giving no promise of favourable quantity or quality of ore.

REFERENCE: J. A. Dresser for Lake Superior Corporation, Sault Ste. Marie, Ont., 1913.

10. District of Parry Sound

TOWNSHIP OF LOUNT

On *lot 136, concession B*, there are several outcrops of magnetite. Diamond-drill exploration of the property was carried on in 1902, when three holes were drilled to depths of 29, 31, and 74 feet, respectively. The holes cut several veins or bands of ore, for the most part of narrow width.

On *lot 137, concession B*, a drill-hole put down in 1902 to a depth of 50 feet in search of iron ore, cut only hornblende and mica schist.

On *lot 32, concession VIII*, reported occurrences of magnetite were explored by diamond drill in 1902. Two holes were drilled to depths of 51 and 30 feet, respectively. The formation drilled consisted of hornblende gneiss and hornblende schist. In each hole a narrow vein of magnetite was cut, but the magnetite deposits were found to be very limited in length and depth.

REFERENCE: Ontario Bureau of Mines, 1903, pp. 50-51.

Magnetawan Mine.—This property covers lots 16 and 17, concession III, and the mining rights of lots 125, 126, and 127, concession A, in the township of Lount, and is reached by a 14-mile road northwesterly from Sundridge station on the Grand Trunk railway.

Some prospecting work was carried on in 1901, and an open trench cut along an ore body for a distance of 50 feet. The average width of the trench is 10 feet, and the depth ranges from 12 to 22 feet. From the trench, about 500 tons of ore have been taken out. Exploratory work was also done on some of the other lots, on which several exposures of magnetite are reported.

The formation is a dark green to black garnetiferous diorite, in which occur bodies of magnetite. The strike, dip, and other characteristics are, however, not determinable on account of the small amount of work yet done. The developed body is apparently a lens trending north and south about 10 feet wide, in some places consisting of practically clean ore and in others intermixed with dark green hornblende which also lines the walls.

REFERENCE: W. E. H. Carter, Ontario Bureau of Mines, 1902, p. 262.

Over a large area in *concessions XII, XIII, and XIV*, pockets of magnetite occur plentifully, but no deposit of ore of encouraging size has been located.

REFERENCES: P. A. Gough for R. H. Flaherty, Port Arthur, Ont., 1903.
H. E. Knobel for R. H. Flaherty, Port Arthur, Ont., 1903.

11. County of Haliburton

TOWNSHIP OF LUTTERWORTH

The *Paxton Mine* property comprises lot 5, concession V, and lot 5, concession VI. The mine is located about 2½ miles from Kinmount on the Haliburton branch of the Grand Trunk railway. A considerable amount of ore is reported to have been shipped from this mine, but the mine has not been operated for many years.

The ore is magnetite and occurs in a fine-grained gneiss interstratified with crystalline limestone and amphibolites. The ore body is irregular in width. In one of the main workings it was as much as 35 feet across. This ore body, however, is not all magnetite, but consists largely of various dark, iron-bearing silicates, garnet, pyroxene, etc., with which the magnetite is mingled.

REFERENCE: Adams and Barlow, Geological Survey of Canada, Memoir No. 6, p. 356.

TOWNSHIP OF SNOWDON

The *Victoria mine* is located on lot 20, concession I, and is within half a mile of the Irondale, Bancroft and Ottawa railway. Prior to 1882 it was worked quite extensively, and a considerable tonnage of ore was shipped from it. The ore is magnetite, and it contains a rather large admixture of dark iron-bearing silicates, and has a not inconsiderable amount of pyrrhotite scattered through it.

In 1893 the workings consisted of a trench 240 feet long and about 16 feet wide. The ore lies in crystalline limestone which is occasionally interstratified with pyroxene rock, red garnet rock, and gneiss. The ore body is 7 feet wide at the northern end of the trench, but at the southern end the ore has been practically all replaced by black hornblende and other highly ferruginous silicates.

The following is the result of an analysis of the ore (probably a selected specimen) by Chapman:—

	Per cent.
Ferric oxide	58.35
Ferrous oxide	24.87
Manganese oxide	0.13
Alumina	0.42
Lime	1.43
Magnesia	2.56
Phosphorus	0.07
Sulphur	0.04
Silica	11.17
Titanium dioxide	0.73
Metallic iron	60.19

REFERENCE: Adams and Barlow, Geological Survey of Canada, Memoir No. 6, p. 359.

On *lots 25, 26, and 27, concession IV*, near Howland station on the Irondale, Bancroft and Ottawa railway, there are several outcrops of magnetite. The deposit at the *Howland mine* on lot 26, lies at the contact of a hornblende gneiss and a narrow band of limestone.

The principal working consists of a shaft which has been sunk to a depth of 75 feet on an outcrop of magnetite about 25 feet in diameter. At a depth of 25 feet the work was enlarged by extension towards the walls in the form of an ellipse, the longer axis of which was about 65 feet, and the shorter about 35 feet. This stope was opened from the 25-foot to the 50-foot level, and no wall was encountered. The best ore ranged from 55 to 60 per cent. iron, 0.005 phosphorus, and 0.06 sulphur. Fifteen hundred tons of ore were shipped in 1881 and 1882.

REFERENCES: C. J. Pusey, Report of the Ontario Royal Commission, p. 131.
Adams and Barlow, Geological Survey of Canada, Memoir No. 6, p. 361.

The *Imperial mine*, lot 23, concession V, is situated on the north side of the Irondale, Bancroft and Ottawa railway, close to the track and just east of Irondale station. The material taken out as ore is composed essentially of olivine and augite, with a smaller amount of hornblende and feldspar. Only a very few grains of iron ore occur scattered through the rock.

REFERENCE: Adams and Barlow, Geological Survey of Canada, Memoir No. 6, p. 262.

TOWNSHIP OF GLAMORGAN

On *lots 29, 30, and 32, concession I*, small stringers of magnetite are found in amphibolite, but the thickest have a width of only 6 inches.

REFERENCE: Adams and Barlow, Geological Survey of Canada, Memoir No. 6, p. 354.

At *Pine lake, lot 35, concession IV*, a large deposit of granular magnetite forms a ledge or succession of ledges rising to a height of 80 to 100 feet above the general level of the district. It is exposed for a length of 1,800 feet, and has a width varying from 70 to 198 feet. A partial analysis of a sample taken from different parts of the deposit is given herewith:—

	Per cent.
Iron	52.04
Sulphur	0.06
Phosphorus	Trace
Titanium dioxide	13.30

Reference: Adams and Barlow, Geological Survey of Canada, Memoir No. 6, p. 353.

Exposures of magnetite have been found on *lot 27, concession XIII*, and magnetic attraction is reported to be very strong over an area 400 feet long and 40 feet wide.

Reference: Adams and Barlow, Geological Survey of Canada, Memoir No. 6, p. 354.

On *lot 27, concession XV*, there are several iron-bearing veins, the largest of which has a maximum width of 4 feet and can be traced for 60 yards. Magnetite constitutes about 50 per cent. of the principal vein, but the quantity is entirely too small to permit of the deposit being considered as a source of iron.

Reference: Adams and Barlow, Geological Survey of Canada, Memoir No. 6, p. 352.

On *lot 30, concession XIII*, a deposit of magnetite with high iron content is reported.

Reference: W. G. Miller, Ontario Bureau of Mines, 1899, p. 202.

12. County of Hastings

TOWNSHIP OF CARLOW

Kennedy Property, (lot 17, concession V).—The Kennedy property lies about 1½ miles northeast of Boulter P.O., and may be reached by wagon road from L'Amable station on the Central Ontario railway, the distance being about 22 miles.

The area is heavily drift-covered. The formation is made up of coarse-grained mica granite, intruding limestone, and amphibolites.

A body of magnetite has been exposed by a surface stripping, 182 feet long and 10 to 34 feet wide. An average sample taken across the ore body gave the following analysis:—

	Per cent.
Iron	43.70
Insoluble	10.50
Sulphur	0.020
Phosphorus	0.118

The general trend of the ore body is N. 25°W. It lies embedded in the granite and is cut in its southern part by a pegmatite dike, 3 feet in width.

Judging from the magnetometric survey, the ore body has a total length of about 220 feet. A short distance farther north the magnetic survey indicates the presence of another ore body of somewhat smaller extent and completely covered by drift. On the *Allison farm*, about 850 feet southwest of the main working, two strong magnetic areas can be seen on the map. The larger strikes in a northwest direction and has an approximate length of about 200 feet. Both are totally covered by drift.

Reference: E. Lindeman, Magnetite Occurrences along the Central Ontario Railway, Mines Branch, Ottawa, No. 184, 1913, p. 21.

On lot 17, concession VII, north of the Kennedy property, a strong but very irregular magnetic attraction indicates the presence of several detached, small ore bodies. Two small outcrops of magnetite and several isolated exposures of white crystalline limestone and amphibolite, apparently inclusions in a large granite intrusive, were observed on this lot.

Reference: E. Lindeman, Magnetite Occurrences along the Central Ontario Railway, Mines Branch, Ottawa, No. 184, 1913, p. 22.

TOWNSHIP OF FARADAY

On the west side of Bow lake on the *north half of lot 21, concession X*, and the *south half of lot 21, concession XI*, several outcrops of magnetite have been found. The distance east of Bancroft on the Central Ontario railway by wagon road is about 6 miles.

The rock formation of the area is to a great extent made up of coarse-grained red granite, the chief constituents of which are a pink feldspar with some hornblende and quartz. Other rocks of the area are crystalline limestone and amphibolites forming smaller or larger inclusions in the granite.

The magnetite, associated with mica, chlorite, apatite, and hornblende, occurs along the contact of the limestone with the granite. There is a rather strong magnetic attraction along the west slope of a hill trending north and south on lot 21, concession XI. Several open cuts and test pits have been made along the hill, but none of these workings have revealed any ore body of sufficient size to be of economic importance. An average sample of the ore gave the following analysis:—

	Per cent.
Iron	51.00
Silica	9.03
Sulphur	0.07
Phosphorus	1.94

Farther south on both sides of the line between concessions X and XI, a strong but irregular attraction is found in several places.

REFERENCE: E. Lindeman, Magnetite Occurrences along the Central Ontario Railway, Mines Branch, Ottawa, No. 184, 1913, p. 22.

TOWNSHIP OF DUNGANNON

On the south side of a ridge running east and west on *lot 30, concession XIII*, an open cut has been made exposing a coarse-grained granite, with some magnetite in narrow bands. The ore is of good character as shown by the following analysis, but the extent of the ore body is very limited, the magnetic attraction being weak only a few feet from the exposure of magnetite:—

	Per cent.
Iron	67.67
Silica	1.20
Sulphur	0.011
Phosphorus	0.042

REFERENCES: E. Lindeman, Magnetite Occurrences along the Central Ontario Railway, Mines Branch, Ottawa, No. 184, 1913, p. 22.
Adams and Barlow, Geological Survey of Canada, Memoir No. 6, p. 351.

TOWNSHIP OF MAYO

Bessemer Mine.—See page 165.

Rankin Property (*Lot 10, Concession IX*).—Here considerable stripping has been done, exposing magnetite associated with hornblende and chlorite schist over an area of 300 feet long and 68 feet wide. A magnetometric survey indicates the possibility of other ore bodies existing on the property.

An analysis of an average sample of the ore exposed in the open cut is given herewith:—

	Per cent.
Iron	42.70
Silica	15.87
Sulphur	0.215
Phosphorus	0.104
Lime	8.08
Magnesia	1.74
Titanium	0.10

REFERENCE: E. Lindeman, Magnetite Occurrences along the Central Ontario Railway, Mines Branch, Ottawa, No. 184, 1913, pp. 19-21.

Childs Property (*Lots 11 and 12, Concession IX*).—See Childs Mine, page 167.

Stevens Property (*Lot 13, Concession IX*).—On this property a number of test pits and strippings have been made. Judging from the magnetometric survey the ore deposits on this lot are of an extremely irregular character, an inference which is well confirmed by the work done.

The character of the ore is indicated by the following analysis of an average sample of the ore exposed:—

	Per cent.
Iron	30.70
Insoluble	23.00
Sulphur	0.015
Phosphorus	0.08

REFERENCE: E. Lindeman, Magnetite Occurrences along the Central Ontario Railway, Mines Branch, Ottawa, No. 184, 1913, pp. 19-21.

TOWNSHIP OF WOLLASTON

Ridge Property.—The property referred to under this name is situated near Ridge post office, about $4\frac{1}{2}$ miles south of Coehill, and includes lots 17 and 18, concession III, and lots 16 and 17, concession II, of Wollaston township. The area is heavily drift-covered and the only exposure of magnetite so far found is situated on lot 17, concession II. Here a thin band of magnetite, lying in mica and hornblende schist, has been revealed by stripping at the foot of the hill. Farther up the hillside, a metamorphic rock, chiefly made up of garnet, is seen in contact with the same schist.

On lot 18, concession III, a test pit is reported to have been sunk through clay to a depth of 27 feet, without reaching bed rock.

The magnetometric survey shows that there is a considerable magnetic attraction on this property, extending in an east and west direction for about half a mile. On this stretch several detached areas are found, which have a magnetic attraction of 60 degrees or more. The two largest occupy a total area of about 74,000 square feet and seem to warrant further investigation in the form of diamond drilling.

REFERENCE: E. Lindeman, Magnetite Occurrences along the Central Ontario Railway, Mines Branch, Ottawa, No. 184, 1913, p. 16.

Coehill Mine (Lots 15 and 16, Concession VIII).—See page 167.

Jenkins Mine (Lots 17 and 18, Concession VIII).—The Jenkins property adjoins the Coehill property to the east. Most of the area is drift-covered and the iron-bearing formation has been exposed in only a few places. The main work has been done on lot 18 and consists of a shallow open pit, 180 feet long, with a maximum width of about 40 feet. Some magnetite, associated with hornblende and pyroxene, is exposed in this pit. Ore of similar character has also been exposed in several other pits and strippings.

The following analyses represent two average samples taken across the exposed ore bodies:—

	No. 1 per cent.	No. 2 per cent.
Iron	46.08	49.50
Insoluble	35.30	34.20
Sulphur	0.52	0.28
Phosphorus	0.054	0.036

Sample No. 1 was taken from the main pit on lot 18, while No. 2 comes from one of the pits on lot 17.

The magnetic attraction of the area is very irregular, changing within small areas from strong positive to strong negative intensity, indicating an irregular and pockety distribution of the magnetite in the country rock. This is well confirmed by the open pit on lot 18.

REFERENCE: E. Lindeman, Magnetite Occurrences along the Central Ontario Railway, Mines Branch, Ottawa, No. 184, 1913, p. 15.

On *lots 9 and 10, concession XV*, there is a large intrusion of gabbro-diorite, through which is disseminated a little titaniferous magnetite. The occurrence is of no economic interest.

REFERENCE: E. Lindeman, Magnetite Occurrences along the Central Ontario Railway, Mines Branch, Ottawa, No. 184, 1913, p. 23.

TOWNSHIP OF LAKE

A body of magnetite is found along the line between *lot 18, concession III*, and *lot 18, concession IV*, about 200 yards east of the Deer river. The ore can be traced along the river bank for a distance of over 200 yards. A width of 6 feet of nearly pure ore is exposed in one place, and a width of $3\frac{1}{2}$ feet in another. The ore occurs in an amphibolite schist. A specimen of the ore was found to contain 60.09 per cent. of metallic iron and to be free from titanic acid.

REFERENCE: Adams and Barlow, Geological Survey of Canada, Memoir No. 6, p. 355.

East of Whetstone lake, on *lots 19 and 20, concession IV*, small patches of magnetite are found associated with amphibolite. Several openings have been made along a ridge running north and south without revealing any ore body of economic importance.

REFERENCE: E. Lindeman, Magnetite Occurrences along the Central Ontario Railway, Mines Branch, Ottawa, No. 184, 1913, p. 16.

On *lot 17, concession XI*, some prospecting has been done on several small patches of titaniferous magnetite associated with gabbro-diorite. An average sample taken from one of the workings gave the following analysis:—

	Per cent.
Iron	52.40
Insoluble	25.25
Sulphur	0.034
Phosphorus	0.012
Titanium	15.31

REFERENCE: E. Lindeman, Magnetite Occurrences along the Central Ontario Railway, Mines Branch, Ottawa, No. 184, 1913, p. 23.

TOWNSHIP OF TUDOR

Orton Mine.—On lot 57, west of Hastings road, stripping and trenching has been done on a few deposits of titaniferous magnetite, which occur at the western end of the lot near the boundary line between the townships of Lake and Tudor. The magnetite occurs in a gabbro-diorite into which it seems to gradually merge. An average sample taken by Lindeman gave the following analysis:—

	Per cent.
Iron	46.60
Insoluble	29.00
Sulphur	0.06
Phosphorus	0.02
Titanium	10.00

In 1912 a small tonnage of ore was mined, and shipments to Belleville for experiments in electric smelting being carried on there by Mr. J. W. Evans, were made in 1912 and 1913.

REFERENCES: E. Lindeman, Magnetite Occurrences along the Central Ontario Railway, Mines Branch, Ottawa, No. 184, 1913, p. 23.
E. T. Corkill, Ontario Bureau of Mines, 1913, p. 135.

Ricketts Iron Mine.—Magnetic iron ore is exposed in several places on lot 17, concession XI. About six pits have been sunk for testing purposes. These pits were supposed to lie on the strike of the ore formation, and were believed to tap the iron ore of one continuous body.

When the underlying rock is exposed, it is seen in places to be banded with iron ore. These bands are very narrow and much contorted, and the ore appears to be too lean even for concentrating purposes.

Magnetic observations taken systematically over the area showed that the ore did not occur as one continuous body, but in a number of pockets. The chances of there being any deposits of economic interest seem small.

REFERENCE: B. F. Haanel, Mines Branch, Summary Report, 1909, p. 114.

St. Charles Mine (Lot 19, Concession XI).—The St. Charles mine is situated on lot 19, concession XI, about half a mile west of McDonald siding on the Central Ontario railway. The ore is magnetite associated with more or less gangue matter consisting of garnet, hornblende, pyroxene, and calcite. It occurs along the contact of crystalline limestone with a medium to fine-grained diorite. There are, according to the magnetometric survey, three deposits in the property. On the principal deposit, pits Nos. 1 and 2 have been made. Strong magnetic disturbances exist along the hillside for a distance of 320 feet. The total area within which magnetite is likely to occur is roughly estimated at 13,500 square feet. A considerable portion of this area, however, contains ore which is either too low in iron or too high in sulphur to be suitable for iron smelting without previous concentration.

An average sample taken across the ore body at opening No. 2 gave the following analysis:—

	Per cent.
Iron	42.00
Insoluble	31.85
Sulphur	0.832
Phosphorus	0.08

During the season of 1900, 3,000 tons of ore are reported to have been shipped from this property to the Hamilton blast furnace. The iron content of this ore varied from 57 to 60 per cent., while the sulphur ranged from 0.5 to 1 per cent.

REFERENCES: E. Lindeman, Magnetite Occurrences along the Central Ontario Railway, Mines Branch, Ottawa, No. 184, 1913, p. 13.
C. De Kalb, Ontario Bureau of Mines, 1900, p. 128.
W. E. H. Carter, Ontario Bureau of Mines, 1901, p. 261.

On the east side of a ridge running approximately north and south on *lot 8, concession XV*, several strippings have been made showing a grey granite in contact with chlorite and horn-

blende schist. Associated with the schist are narrow bands of magnetite. The magnetic attraction is rather strong in places, but none of the workings has so far revealed any ore body of sufficient size to be of economic importance.

REFERENCE: E. Lindeman, Magnetite Occurrences along the Central Ontario Railway, Mines Branch, Ottawa, No. 184, 1913, p. 14.

Baker Mine.—The Baker mine is situated on lot 18, concession XVIII, about 1¾ miles west of Gilmour station on the Central Ontario railway.

The workings consist of three open cuts and a number of test pits on the eastern slope of a ridge running north and south. The ore is a fine-grained magnetite, intermixed with a large amount of gangue matter, chiefly pyroxene and chlorite. It occurs along the contact of crystalline limestone and diorite. Iron pyrites is of common occurrence in the diorite as well as throughout the ore. Judging from the magnetometric survey the ore occurs in small detached bodies or pockets. The largest area of strong magnetic attraction is found around open cut No. 1. The development work done here has, however, so far failed to reveal any ore of economic importance. The ore body opened up in open cut No. 2 has a width of about 25 feet, but the magnetometric survey indicates that its extent is very small. Working No. 3 shows another small pocket of magnetite along the contact of limestone and diorite.

An average sample taken across the ore body at open cut No. 2 gave the following result:—

	Per cent.
Iron	38.70
Insoluble	37.10
Sulphur	3.35
Phosphorus	0.20

REFERENCE: E. Lindeman, Magnetite Occurrences along the Central Ontario Railway, Mines Branch, Ottawa, No. 184, 1913, p. 13.

Emily Mine.—The Emily mine is situated on lot 7, concession XIX, about 1¾ miles northeast of Gilmour station. Chapman[1] describes this as a magnetic ore deposit of considerable extent. He says: "The exposed ore rises in a series of ledges from the level of the ground to a height of from 150 to 180 feet, and extends over a space of at least 1,000 feet in length by 100 feet in breadth." This could not be verified by Lindeman. On lot 7 a somewhat abrupt ridge, chiefly made up of a coarse-grained granite, was found. A large open cut had been made into the hillside showing in places some small patches of magnetite heavily intermixed with gangue matter. The magnetic attraction around the open cut is also very irregular.

REFERENCE: E. Lindeman, Magnetite Occurrences along the Central Ontario Railway, Mines Branch, Ottawa, No. 184, 1913, p. 14.

TOWNSHIP OF MARMORA

The greater part of *lots 12, 13, and 14, concession I,* is occupied by a coarse-grained gabbro-diorite, cut in the most intricate manner by a red granite and pegmatites. Along the contact with the latter rocks, magnetite in small quantities is found in several places disseminated through the gabbro-diorite. Where the magnetite has been found, the magnetic attraction is, however, very feeble and the discoveries so far made are of no economic importance.

REFERENCE: E. Lindeman, Magnetite Occurrences along the Central Ontario Railway, Mines Branch, Ottawa, No. 184, 1913, p. 12.

On *lot 18, concession I* (*Maloney mine*), a few hundred feet south of the Ontario, Belmont, and Northern railway, a deposit of magnetite has been exposed. The workings consist of two open pits and a stripping. Between the three workings a magnetic attraction exists for a distance of about 280 feet. The ore body, as exposed in the main pit, shows a width of about 25 feet. It consists of magnetite mixed with a considerable amount of gangue minerals. An average sample of the ore taken by Lindeman, gave the following analysis:—

	Per cent.
Iron	47.00
Insoluble	21.03
Sulphur	0.50
Phosphorus	0.137
Titanium	0.25

On the hill immediately south of the workings, numerous outcrops of gabbro-diorite can be seen, while an outcrop of crystalline limestone was observed near the railway track to the north.

REFERENCE: E. Lindeman, Magnetite Occurrences along the Central Ontario Railway, Mines Branch, Ottawa, No. 184, 1913, p. 11.

[1]Chapman, E. J., Transactions Roy. Soc., Canada, 1885, section III, p. 12.

On a hill running east and west, on *lot 17, concession II*, two test pits have been sunk about 150 feet apart; these show some magnetite disseminated throughout a gabbro-diorite similar in character to that seen on the Maloney property. The distance from the workings to the Ontario, Belmont, and Northern railway is about 500 feet.

An average sample of the iron-bearing rock gave the following analysis:—

	Per cent.
Iron	34.80
Insoluble	43.80
Sulphur	0.41
Phosphorus	0.134
Titanium	0.10

REFERENCE: E. Lindeman, Magnetite Occurrences along the Central Ontario Railway, Mines Branch, Ottawa, No. 184, 1913.

TOWNSHIP OF MADOC

The *Seymour mine* was one of the earliest producers of iron ore in the district, but it has been abandoned for many years. It is located on the west half of lot 11, concession V, about 4 miles north of the Village of Madoc. The old shaft is said to be 125 feet deep.

The old open cut has a length of about 200 feet, with a width ranging from 18 to 25 feet. The ore consists of a fine-grained magnetite, associated with chlorite, pyroxene, and hornblende. It is surrounded by a large granite eruptive. The magnetic attraction near the workings is very weak.

REFERENCES: C. De Kalb, Ontario Bureau of Mines, 1901, p. 129.
E. Lindeman, Magnetite Occurrences along the Central Ontario Railway, Mines Branch, Ottawa, No. 184, 1913, p. 12.

The *Wallbridge mine* is situated on lot 12, concession V. A considerable amount of hematite is reported to have been shipped from this mine but no accurate information is available. The mine apparently was last operated in 1900. Some of the ore mined at that time was shipped in 1918.

REFERENCE: C. De Kalb, Ontario Bureau of Mines, 1901, p. 129.

The *Brennan mine*, located on lot 7, concession VI, was in operation in 1901, when 250 tons of hematite were shipped to the blast furnace at Radnor Forges, Quebec. Work was confined to the surface and consisted merely of stripping and trenching without exposing any large body of hematite.

REFERENCE: W. E. H. Carter, Ontario Bureau of Mines, 1902, p. 262.

Exploratory operations are known to have been carried on at the following properties, and from some of them ore shipments have been made, but no accurate information concerning these operations is available:—

Cook and Thompson mine (lot 15, concession V).
St. Charles mine (lot 4, concession VI).
Cameron mine (lot 9, concession VI).
49-Acre mine (lot 10, concession VI).
Miller mine (lot 12, concession VI).
Sexsmith mine (lot 8, concession VII).
Farrell mine (lot 9, concession VII).

13. County of Peterborough

TOWNSHIP OF ANSTRUTHER

Claims have been taken up for iron on the south halves of *lots 26 and 27, concession XV*, about 9 miles south of Tory Hill station on the Irondale, Bancroft and Ottawa railway.

The owners claim the existence of an ore-bearing zone 1,600 feet long by 200 feet wide, in which there occur bands of ore with widths up to 15 feet. Two shafts have been sunk in ore to a depth of 25 feet. The following analyses have been furnished:—

	SURFACE ORE per cent.	ORE DEPTH 10 FEET per cent.	ORE DEPTH 25 FEET per cent.
Iron	47.00	52.25	52.05
Silica	.....	.....	20.52
Sulphur	0.15	Nil	0.57
Phosphorus	0.03	.....	0.024
Titanium	Nil	Nil	.....

REFERENCE: S. Lawrence for P. J. Dwyer, 91 Medland Crescent, Toronto, Ont., 1914.

TOWNSHIP OF CHANDOS

On *lot 28, concession I*, an open cut 53 by 21 feet, has been made into a hill, exposing a dark-coloured amphibolite, associated with some magnetite. Magnetic indications of several other deposits in the immediate vicinity were also noticed, but they all appeared to be of very small extent.

REFERENCE: E. Lindeman, Magnetite Occurrences along the Central Ontario Railway, Mines Branch, Ottawa, No. 184, 1913, p. 14.

TOWNSHIP OF BELMONT

Blairton mine (Lots 7 and 8, Concession I).—See page 163.

Belmont (or Ledyard) mine (Lot 19, Concession I).—See page 164.

14. County of Renfrew

TOWNSHIP OF GRATTAN

On the *Parks property*, lot 16, concession VIII, outcrops of banded ore formation in gneiss can be traced for 1,300 feet. In some places the ore band is 50 feet wide. It is reported that the ore carried too high a percentage of titanium to be attractive to furnacemen.

REFERENCE: P. A. Gough and W. W. J. Croze for R. H. Flaherty, Port Arthur, Ont.

The ore deposits on lot 16, concession IX, are known as *Radnor mine*. The distance from the mine to Caldwell station on the Ottawa-Parry Sound branch of the Grand Trunk railway is 6 miles, and the wagon haul to the shipping siding is 4¼ miles.

The ore, which is a coarse-grained granular magnetite, occurs in rather narrow lenses varying in maximum thickness from 4 to 25 feet. The ore lenses are found in line for a distance of about 1,300 feet, the series of outcrops forming roughly a semi-circle, towards the centre of which the ore horizon dips at an angle of about 35 degrees. The country rock is a biotite gneiss, and this is cut by pegmatite dikes, a few of which cut the ore lenses too.

A small amount of diamond-drill work was done in 1900 and 1904, but the results offered no encouragement for expecting any large tonnage of ore.

The ore lenses outcropping on surface were exploited by open pit methods of mining which necessarily became very expensive at depth, because of the fairly flat dip of the ore bodies. Eight pits were operated.

The mine operated almost continuously from 1901 to 1907, during which time there was shipped approximately 18,824 net tons of ore, all of which went to Radnor Forges, Que. Shipping ore had an iron content of 48 per cent. and upwards; all leaner ore was left in stock at the mine.

Magnetic concentration experiments on the low-grade ores gave very favourable results.

REFERENCES: E. T. Corkill, Ontario Bureau of Mines, 1905, p. 71.
G. C. McKenzie, Ontario Bureau of Mines, 1908, p. 220.
G. C. McKenzie, Ontario Bureau of Mines, 1910, p. 169.
R. W. Ells, Geological Survey of Canada, Vol. XIV, p. 65J.

On the *Big Jim property*, lot 17, concession X, there are occurrences of magnetite similar to those at Radnor mine, but after a little exploration in 1902 the property was abandoned.

REFERENCE: W. E. H. Carter, Ontario Bureau of Mines, 1903, p. 114.

TOWNSHIP OF BROUGHAM

On *lots 7 and 8, concession X*, there are some six-inch seams of granular magnetite in a contact zone between granitic gneiss and crystalline limestone. The ore is of good quality, but the quantity is too small to be of interest.

REFERENCE: D. B. Rockwell for R. H. Flaherty, Port Arthur, Ont., 1910.

On *lot 14, concession XVIII*, near Dacre, a deposit of magnetite was worked in 1901.

REFERENCE: R. W. Ells, Geological Survey of Canada, Vol. XIV, p. 64J.

TOWNSHIP OF BLITHFIELD

On *lot 13, concession I*, about 3 miles south of Calabogie, in a side rock-cut on the Kingston and Pembroke railway, a vein of magnetite, dipping at 35 degrees to the east, is exposed for a length of about 75 feet and for a height of eight feet, without the foot-wall being shown.

The face of the rock-cut is a little over 50 feet high, with a rising hill to the east. On this hill the magnetic attraction is weak; but numerous readings taken along the edge of the swamp to the west of the railway, and in some places as much as 200 feet from it, varied from -17 to -22 degrees.

More readings could not be taken on account of the swamp.

An average sample of the exposed portion of the vein gives the following analysis:—

	Per cent.
Iron	38.80
Insoluble	37.40
Sulphur	0.179
Phosphorus	0.013
Titanic acid	4.96

REFERENCE: H. Fréchette, Mines Branch, Summary Report, 1909.

TOWNSHIP OF BAGOT

On *lot 28, concession VI*, to the southeast side of the road which runs through that lot, a pit has been sunk to a depth of 18 feet in magnetite. The ore is found in alternating layers of high-grade magnetite and a gneissic rock carrying magnetite. It dips to the south at about 15°. In the pit the ore is exposed for a thickness of 8 feet, but the foot-wall was not uncovered.

About 100 feet to the east of the pit there is a mass of gneiss; and to the north, a large exposure of crystalline limestone.

No magnetometric survey was made.

The following analysis is from an average sample taken in the pit:—

	Per cent.
Iron	42.81
Insoluble	38.00
Sulphur	0.068
Phosphorus	0.006
Titanic acid	1.37

REFERENCE: H. Fréchette, Mines Branch, Summary Report, 1909, p. 86.

Culhane Mine.—The Culhane mine is situated on lot 21, concession VII. It lies on the south shore of Norway lake, about 3 miles northeast of Calabogie station. Magnetite occurs here in small irregular bands or lenses in a series of crystalline limestones, interbedded with amphibolite schist. The general strike of the iron-bearing formation is northeast with a dip of 30 degrees towards the northwest. There are four workings on the property, the locations of which are shown on magnetometric map No. 252, Mines Branch, Ottawa. This map shows that the most promising area lies in the northeast part of the field, immediately south of reference post No. 40. At this point a small open cut about 35 feet long and 10 feet wide has been made into the hillside, exposing some limestone interbanded with amphibolites. From the bottom of this cut a vertical shaft has been sunk in search for ore, but evidently with negative results. A small amount of magnetite, disseminated throughout the schists, is probably the cause of the strong magnetic attraction found here.

About 250 feet southwest of the last-mentioned open cut lies the main shaft, 70 feet deep, from which a few hundred tons of ore have been extracted and piled up nearby. At its mouth some magnetite intermixed with hornblende and mica schist is exposed, but judging from the irregular magnetic attraction there is no prospect of finding any ore body of impor ance here.

Working No. 3 consists of an open cut exposing a schistose amphibolite, through which a small amount of magnetite is disseminated.

No ore has been shipped from this mine.

REFERENCES: E. D. Ingall, Geological Survey of Canada, Vol. XII, p. 62-I.
E. Lindeman, Magnetite Occurrences near Calabogie, Mines Branch, Ottawa, No. 254, 1914, p. 15
T. B. Caldwell, Lanark, Ont., 1915.

Campbell or No. 4 Mine.—The workings known as the Campbell or No. 4 mine are situated on lot 16, concession VIII, close to the "T.B." pit of the Caldwell mine to be described later, and are about 1½ miles east of Calabogie village on the Kingston and Pembroke railway.

The workings consist of an open cut, 100 by 40 feet, and three test pits, exposing dark-coloured amphibolites with considerable mica and chlorite. The magnetic attraction of this area is very irregular, indicating a pockety distribution of the magnetite in the country rock.

REFERENCES: E. D. Ingall, Geological Survey of Canada. Vol, XII, p. 60-I.
E. Lindeman, Magnetite Occurrences near Calabogie, Mines Branch, Ottawa, No. 254, 1914, p. 14.

Caldwell Mine.—The Caldwell mine is situated on the east half of lot 16, concession IX, about one mile east of Calabogie station.

Work was begun on this property in 1883, and subsequently a number of openings were made by the Hamilton Steel and Iron Company who carried on mining operations for a short time. The total amount of ore shipped from the property is reported to have been 10,000 tons. The greater portion of this went to the blast furnace at Hamilton. An average analysis of a shipment of seven cars to that point is given herewith:—

	Per cent.
Iron	58.30
Silica	5.47
Sulphur	Trace
Phosphorus	0.137
Alumina	3.68
Lime	2.03
Magnesia	0.15

The railway freight to Hamilton was $1.80 per gross ton.

The ore consists of a medium-grained magnetite which occurs in small, irregular masses or lenses, associated with a dark-coloured, basic, highly schistose amphibolite, composed chiefly of feldspar, hornblende, and biotite. The general strike of the iron-bearing rocks is northeast, and the dip about 40 degrees towards the southeast.

There are a great number of open cuts and test pits on this property, the locations of which are shown on magnetometric map No. 249, accompanying Lindeman's report. The Tommy R pit is an open pit and trench extending about 110 feet with a width ranging from 15 to 45 feet. The iron-bearing formation revealed by this working consists of bands of magnetite interbanded with amphibolite schists, through which individual grains of magnetite often are disseminated. The average iron content of the ore in this pit is, therefore, rather low. The following analysis represents a sample taken by Lindeman across the exposure:—

	Per cent.
Iron	38.30
Insoluble	16.10
Sulphur	0.02
Phosphorus	0.233

From 500 to 900 feet northeast of the Tommy R pit, several small deposits of magnetite have been revealed by numerous pits and trenches. They all lie in a dark-coloured amphibolite schist, with which they are often found interbanded. In some instances the contacts with the adjacent amphibolites are sharp, and the ore of an exceedingly good quality, but in many cases the ore and the country rock grade imperceptibly into each other. The width of the richer ore layers ranges from 2 to 7 feet, while their length is rarely more than 150 feet, and usually less.

A sample taken across one of these deposits gave the following analysis:—

	Per cent.
Iron	60.91
Silica	4.60
Sulphur	0.10
Phosphorus	0.575
Alumina	3.60
Lime	1.77
Magnesia	2.83

The T.B. pit is an irregular, open working about 90 by 80 feet, and reported to be 60 feet deep. Dark-coloured amphibolites, associated with mica and small particles of magnetite, are exposed in the upper portion of the pit.

References: E. D. Ingall, Geological Survey of Canada, Vol. XVI, p. 58-I.
E. Lindeman, Magnetite Occurrences near Calabogie, Mines Branch, Ottawa, No. 254, 1914, p. 13.
T. B. Caldwell, Lanark, Ont., 1915.

On the west half of *lot 16, concession IX*, a shallow pit has been sunk at the edge of a beaver meadow exposing some magnetite associated with amphibolites. A sample from an ore-pile near the pit gave the following analysis:—

	Per cent.
Iron	47.81
Silica	15.00
Sulphur	0.015
Phosphorus	0.39
Alumina	3.85
Lime	4.86
Magnesia	7.05

REFERENCES: E. D. Ingall, Geological Survey of Canada, Vol. XII, p. 57-I.
E. Lindeman, Magnetite Occurrences near Calabogie, Mines Branch, Ottawa, No. 254, 1914.

On *lot 18, concession IX*, about 1 mile northwest of Calabogie village, several pits have been sunk showing a vein of magnetite varying from $1\frac{1}{2}$ to 3 feet in thickness. With the magnetite there is mixed a little hematite. The vein is enclosed in crystalline limestone. Magnetic attraction in the vicinity is very feeble.

REFERENCE: H. Fréchette, Mines Branch, Summary Report, 1909, p. 85.

Martel or Wilson Mine.—The Martel or Wilson mine, is situated on lot 13, concession X, about $1\frac{3}{4}$ miles southeast of the village of Calabogie. In a flat of low ground, two openings have been made about 350 feet apart.

The principal mining operations have been confined to pit No. 1 (see map No. 253 accompanying Lindeman's report). From this pit 2,000 tons of good magnetite are reported to have been extracted and shipped. Pit No. 2 is a mere prospect hole. The ore, judging from what little shows above water around the edge of pit No. 1, occurs in a dark green, almost black, diorite. Lindeman's magnetometric map shows the magnetic attraction to be very irregular, and gives little encouragement for finding any ore body of importance. It is reported that 4,000 tons of ore have been shipped from this mine.

REFERENCES: E. D. Ingall, Geological Survey of Canada, Vol. XII, p. 61-I.
E. Lindeman, Magnetite Occurrences near Calabogie, Mines Branch, Ottawa, No. 254, 1914, p. 15.

Bluff Point Mine.—The Bluff Point mine is situated on lot 16, concession X, and lot 16, concession XI, on the northeast side of Calabogie lake and about 1 mile south of Calabogie village. The old workings are connected with the main line of the Kingston-Pembroke railway by a spur line about three-quarters of a mile in length.

The magnetite occurs in irregularly-shaped lenses along the contact of crystalline limestone and a dark grey amphibolite. The general strike is northeast, with a dip ranging from 30 to 45 degrees towards the southeast.

The workings consist of three shafts and several open cuts. The deepest shaft is 300 feet, and in one of the open cuts magnetite is exposed showing a width of 4 feet.

The following analysis represents a shipment of ore made by the Canada Iron Furnace Company:—

	Per cent.
Iron	59.50
Silica	9.10
Sulphur	0.16
Phosphorus	0.17
Alumina	4.80
Lime	0.01

It may seem from magnetometric map No. 251 accompanying Lindeman's report that the strong magnetic attraction is confined to a few small areas round pits Nos. 1, 2, 4, and 5, indicating a very pockety distribution of the ore, none of the ore bodies being 100 feet in length.

Mining operations were commenced at Bluff Point in 1881, but closed in 1883; they were resumed in 1886, but again discontinued the following year. In 1894 a few shipments of ore were made from stock piles to Radnor, Que., by the Canada Iron Furnace Company. The following years a small amount of mining was done, but since 1901 the property has been idle.

The total amount of ore shipped from Bluff Point and Campbell mines is reported to have been about 9,000 tons.

REFERENCES: E. D. Ingall, Geological Survey of Canada, Vol. XII, p. 55-I.
E. Lindeman, Magnetite Occurrences near Calabogie, Mines Branch, Ottawa, No. 254, 1914.

On *lot 18, concession XI*, magnetic disturbance was observed near the main road which follows the west shore of Calabogie lake.

A magnetometric survey was made which indicates the existence of magnetite in a series of small pockets extending for about 600 feet along the road and crossing it.

REFERENCE: H. Fréchette, Summary Report of Mines Branch, 1909, p. 85.

Williams or Black Bay Mine.—This mine is situated on lot 22, concession XI, about 2 miles northwest of Calabogie village.

The magnetite occurs along the contact of crystalline limestone and a basic amphibolite. The general strike is about northeast, and judging from the inclination of the workings the dip is about 40 degrees towards the northwest. The limestone forms the foot-wall and is found to the south of the working, while the amphibolite lies to the north.

The proved length of the deposit in the main working is about 240 feet, but towards both ends of the pit the ore body becomes indefinite, the ore ground being represented by amphi-

bolite containing some disseminated magnetite. The open cut has a face of about 15 feet, beyond which the ore has been followed downward in several inclines along the dip. The depths of these inclines are reported by E. D. Ingall to vary from 10 to 80 feet.

A sample taken from an ore pile gave the following analysis:—

	Per cent.
Iron	51.50
Insoluble	15.85

Judging from the magnetometric survey the prospects of finding any ore body of importance on this property are not encouraging.

Shipments of 25,000 tons of ore are reported to have been made from this mine to Cleveland, Ohio.

REFERENCES: E. D. Ingall, Geological Survey of Canada, Vol. XII, p. 64-I.
E. Lindeman, Magnetite Occurrences near Calabogie, Mines Branch, Ottawa, No. 254, 1914, p. 16.
T. B. Caldwell, Lanark, Ont., 1915.

15. County of Frontenac

TOWNSHIP OF SOUTH CANONTO

On the south end of *lot 26, concession VI*, a pit has been opened on a vein of magnetite. An outcrop near the pit shows the ore to be fairly free from intermixed rock. A sample taken from a small ore pile near the pit gave the following analysis:—

	Per cent.
Iron	44.00
Insoluble	31.60
Sulphur	0.044
Phosphorus	0.045
Lime	0.70
Manganese	0.10
Titanic acid	Trace

The vein, which runs north and south, was traced by means of a mining compass for about 350 feet into lot 26, concession V. The width of the vein appears to be about 10 feet.

REFERENCE: H. Fréchette, Mines Branch, Summary Report, 1909, p. 87.

TOWNSHIP OF PALMERSTON

Mississippi or Robertsville Mine, and Mary Mine.—On an iron-bearing area about one mile northeast of Robertsville station on the Kingston and Pembroke railway are located the Mississippi or Robertsville mine (lot 3, concession IX), and the Mary mine (lot 4, concession IX). A spur about a mile in length connects the workings with the railway.

The rock immediately enclosing the ore is a dark, compact, heavy basic rock, probably diorite. The magnetite is found intermixed through the rock in irregular patches, in veinlets, and as scattered grains. In some of the workings there are ore pockets which would yield a considerable tonnage of ore, but about 50 per cent. of the surface exposed in the workings is said to be gangue.

Eight workings are described by Ingall who made examinations of the property in 1895 and 1900. The largest is a pit, 108 feet long and 200 feet deep, which has a width of 50 feet in places.

A series of dip-needle readings taken systematically over the property showed no particular attraction except in the immediate vicinity of the main pit and between pits Nos. 7 and 8.

A number of diamond-drill holes have been put down, but the records of these are not available.

The Mississippi Mining Company, which operated this mine in the eighties, is said to have shipped thirty or thousand tons of ore to American smelters.

REFERENCE: E. D. Ingall, Geological Survey of Canada, Vol. XII, p. 29-I.

About a mile west of Lavant station on the Kingston and Pembroke railway, on *lots 27 and 28, concession XI*, a little work has been done on an occurrence of magnetite. The magnetite occurs in bands of various thicknesses at the contact of limestone and grey gneiss. Actinolite and chlorite are of frequent occurrence in the ore.

REFERENCE: E. D. Ingall, Geological Survey of Canada, Vol. XII, p. 32-I.

TOWNSHIP OF BEDFORD

On *lot 5, concession II*, across a bay of Thirty Island lake from the Glendower mine, there is a small prospect pit from which some magnetite has been extracted. An exposure of ore 25 feet long and 15 feet wide may be seen in the pit, but nothing definite seems to have been proven about the extent of the ore body. A little pile of ore standing beside the pit shows a considerable proportion of intermixed foreign material, amongst which are calcite and considerable pyrite.

REFERENCE: E. D. Ingall, Geological Survey of Canada, Vol. XII, p. 27-I.

Glendower Mine.—This mine is situated within 4 miles of Bedford station on the Kingston and Pembroke railway, with which point it is connected by a branch line. The main workings are on lot 6, concession II, and lot 6, concession III.

The ore bodies developed on the workings are in gneissic rocks, immediately at or near their contact with a belt of crystalline limestone.

Pit No. 1 was the principal working. At its entrance a shaft with a reported depth of 180 feet was sunk. A considerable tonnage of ore is said to have been extracted from it. On the surface the ore body thins out as it is followed west. At No. 2 pit a shaft of unknown depth was sunk. No tonnage of good ore remains exposed at either pits Nos. 1 or 2, or at any other pit. At pit No. 9, there is an ore body consisting of magnetite and apatite in about equal proportions, from which a small tonnage was shipped to meet a demand for phosphatic ore from the Hamilton smelter.

A number of diamond-drill holes were put down subsequent to the closing of the mine and prior to 1895. Data which were furnished Mr. Ingall, concerning these holes, indicated the existence of a rib of ore 20 to 30 feet thick but of undetermined length, and a great deal of intermixed magnetite and gangue matter. Dip needle readings taken do not seem to have furnished any conclusive indications of ore bodies.

The mine was first operated prior to 1873 by the owners, and from 1873 to 1880 by the Glendower Company. The Zanesville Company, which acquired the property about 1883, built the railway spur to the mine and operated the mine for four or five years. In 1895 the mine had been idle for several years. In 1899 the Hamilton Steel and Iron Company mined and shipped a little ore. The total shipments to 1895 are estimated to have been about 50,000 tons.

The Glendower Company is reported to have shipped no ore running less than 60 per cent. iron, but the Zanesville Company is said to have disposed of 50 per cent. ore. The earlier shipments are said to have been reasonably free from sulphur; but the latter ones, coming from depths greater than 180 feet, are said to have had an objectionable percentage of it. A pile of several hundred tons lying at No. 1 shaft in 1895 showed the ore to contain a considerable proportion of calcite and pyrite.

REFERENCE: E. D. Ingall, Geological Survey of Canada, Vol. XII, p. 20-I.

On *lot 3, concession III*, there is a large area of gneiss in which are impregnations of magnetite and isolated bodies of magnetite of varying size and quality. A diamond-drill hole was put down 300 feet to explore the ground, but the results were unfavourable.

REFERENCES: E. D. Ingall, Geological Survey of Canada, Vol. XII, p. 29-I.
E. Lindeman, Report of Superintendent of Mines, 1907, p. 33.

Black Lake Mine.—About a mile and a half northeast from the main workings of the Glendower mine, on lots 7 and 8, concession IV, are situated the Black Lake deposits.

Deposit No. 1 occurs on a small peninsula at the south end of the lake. A few small cuts have been made here, and the faces of these show a dark green hornblende rock with impregnations of magnetite and calcite. The magnetic survey shows that the deposit is of very small extent.

Deposit No. 2 occurs on an island close to the west shore of the lake. An open cut has been dug here and some ore is said to have been taken out. Magnetite and iron pyrite are seen distributed through the rock formation and the decomposition of the latter gives the rock a rusty and rotted appearance.

Deposit No. 3 occurs on another island about 900 feet northeast of deposit No. 2, and is of the same nature as the two former. The rock is, however, not so much altered. None of the deposits are of economic value.

Three or four thousand tons of ore was shipped from this property in 1881 and 1882.

REFERENCES: E. D. Ingall, Geological Survey of Canada, Vol. XII, p. 28-I.
E. Lindeman, Summary Report of the Superintendent of Mines for 1907, p. 32.

On *lot 2, concession VII*, north of Birch lake, and at a few other points in the neighbourhood, are patches of ochreous sandstone, with small veins and stringers of hematite either in the sandstone itself or in the underlying limestone. The quantity of ore in every case is too small to be of economic interest.

REFERENCE: E. D. Ingall, Geological Survey of Canada, Vol. XII, p. 76-I.

On *lots 1 and 2, concession XIV, lots 1, 2, and 3, concession XV, and lots 1, 2, 3, and 4, concession XVI,* near Lake Opinicon, there are small pockets of hematite in cavities in limestone. All are too small to be of economic interest. Two drill holes put down in 1900 gave unfavourable results.

REFERENCE: J. Kellerschon for R. H. Flaherty, Port Arthur, Ont.

TOWNSHIP OF PORTLAND

Smith Lands.—On the Smith lands, lot 5, concession XIII, numerous test pits were made, and two diamond-drill holes were put down. The test pits showed small pockets of ore in cavities in limestone, but the drilling gave unsatisfactory results.

REFERENCE: J. Kellerschon for R. H. Flaherty, Port Arthur, Ont., 1900.

16. County of Lanark

TOWNSHIP OF LAVANT

Radenhurst and Caldwell Mines.—These properties comprise the west half of lot 22, concession III, and the east half of lot 22, concession IV, and they are located close to the Kingston and Pembroke railway about a mile north of Flower station.

The development consists of a number of pits and strippings spread over a distance of about 1,500 feet in a general east-northeast direction. The dip is to the south and varies from 60 to 70 degrees. The rocks consist of rusty schists and gneisses of various compositions. No limestone is visible in the immediate vicinity of the workings.

The ore occurs as small seams and ribs of magnetite, associated with chlorite and rusty schistose rocks. The ribs and seams are generally parallel to the strike of the enclosing rocks.

Judging from the general rustiness of the rock and from the evidence of the ore piles, pyrites must be plentiful.

REFERENCES: E. D. Ingall, Geological Survey of Canada, Vol. XII, p. 52-I.
T. B. Caldwell, Lanark, Ont., 1915.

Wilbur Mine.—The Wilbur mine workings are located on lot 4, concession XII, and lot 4, concession XIII, a short distance east of the Kingston and Pembroke railway, with which they are connected by a spur about a mile long.

Nine different openings are to be seen on the property. With the exception of No. 3, however, these have all been long abandoned and nothing worthy of special description can be seen at them. Judging by the dumps several of them must have been of considerable extent.

The magnetite occurs as a series of detached ore bodies in gneissic rocks at their contact with underlying limestone. The chain of ore bodies has a general trend of northeast, while the dip of the formation and of the workings on the ore, is to the south at angles varying from 25 to 40 degrees. The contact between the gneiss and the limestone at the western pits is fairly sharply defined, but in the vicinity of the eastern pits the two series of rocks seem to be separated by an alteration zone in which chlorite, epidote, etc., are found, evidently alteration products of the gneiss.

Judging from a magnetometric survey made by B. F. Haanel, the ore deposits are extremely pockety; and this inference is reported to have been corroborated during the operations of the Wilbur Iron Ore Company in 1907 and 1908. These operations demonstrated, too, that extensive cobbing was necessary to produce a shipping grade of ore.

The following analysis represents a carload of ore shipped to Sault Ste. Marie; but the average iron content of the total shipments to that point was much lower.

	Per cent.
Iron	56.69
Silica	6.20
Sulphur	0.01
Phosphorus	0.01
Alumina	2.56
Lime	2.00
Magnesia	6.84
Manganese oxide	0.20

A very considerable amount of diamond drilling was done on the property prior to 1900, but the records of none of this work are available.

The mine was first opened up many years ago, and was worked for several years under lease by the Kingston and Pembroke Mining Company, during which time shipments of 125,000 tons are reported to have been made. In 1901 the mine was developed by the owner, the leases having lapsed. In 1907 the Wilbur Iron Ore Company, leased the property, and during 1907 and 1908

shipped 21,892 tons of ore to the Algoma Steel Company, Sault Ste. Marie. After being closed down for a couple of years the mine was re-opened in 1910 by the Hawthorne Silver and Iron Mines Company, but no shipments were made.

REFERENCES: E. D. Ingall, Geological Survey of Canada, Vol. XII, p. 46-I.
B. F. Haanel, Report of Superintendent of Mines, Ottawa, 1906, p. 5.
E. T. Corkill, Ontario Bureau of Mines, 1907, p. 86.
E. T. Corkill, Ontario Bureau of Mines, 1911, p. 108.
R. H. Flaherty, Port Arthur, Ont.

TOWNSHIP OF DARLING

At the northeast end of *lot 17, concession II*, amphibolites are found which are impregnated in a great many places with magnetite in varying proportions. Occasionally the rock is rich enough in magnetite to be described as a lean ore. At the west end of the hill, magnetometric readings indicate the presence of a fairly large and continuous body of low-grade ore which would require magnetic concentration. No satisfactory sample could be obtained at this point. The iron would probably run about 30 per cent.

REFERENCE: H. Fréchette, Mines Branch, Summary Report, 1909, p. 85.

Southwest of the Darling road, on the southwest half of *lot 22, concession III*, and along the north side of a hill, there are a number of large trenches which were opened about twenty years ago and from which ore was shipped. These trenches have caved in and trees are now growing in the bottom of some of them. No reliable information could be obtained regarding the extent of the ore.

Magnetometric readings taken in the vicinity of these trenches were low and irregular, and do not indicate the presence of a large body of magnetite.

On the opposite side of the Darling road, on the northeast half of the same lot, a pit was recently opened on a small pocket of magnetite.

REFERENCE: H. Fréchette, Mines Branch, Summary Report, 1909, p. 85.

On *lot 20, concession IV*, and *lot 20, concession V*, the amphibolite rocks are impregnated with magnetite. The magnetometric survey shows the impregnations to be very irregular. The deposits are not considered of economic importance. A surface sample gave the following analysis:—

	Per cent.
Iron	24.21
Insoluble	53.00
Sulphur	0.031
Phosphorus	0.468

REFERENCE: H. Fréchette, Mines Branch, Summary Report, 1909, p. 85.

On *lot 22, concession IV*, several pits have been opened on small pockets of magnetite, and some shipments of ore have been made, but judging from the magnetometric readings, these deposits cannot be considered of any importance.

REFERENCE: H. Fréchette, Summary Report, Mines Branch, 1909, p. 84.

On *lot 22, concession V*, a pit has been sunk about 20 feet into a small pocket of fine-grained magnetite. A picked sample of the magnetite gave the following analysis:—

	Per cent.
Iron	61.17
Insoluble	8.34
Sulphur	0.042
Phosphorus	0.046

REFERENCE: H. Fréchette, Mines Branch, Summary Report, 1909, p. 85.

Yuill Mine.—The Yuill mine is located on lot 25, concession V. The workings consist of an open pit, 100 feet long, 30 to 40 feet wide, and a little over 70 feet deep. At the east end of the pit the magnetite band is 6 feet wide, and at the west end it is 10 feet wide. The ore dips steeply to the south, having a foot-wall of diorite and schist and a hanging wall of crystalline limestone. Small veins of pyrite occur in the ore. A sample of ore exposed in the workings and on the dumps gave the following analysis:—

	Per cent.
Iron	63.00
Insoluble	10.08
Sulphur	0.006
Phosphorus	0.025

REFERENCE: H. Fréchette, Mines Branch, Summary Report, 1909, p. 83.

On *lot 23, concession XI*, there is exposed a deposit of hematite, 30 to 35 feet long and 2 feet wide. An average sample gave the following analysis:—

	Per cent.
Iron	62.52
Insoluble	3.20
Sulphur	0.004
Phosphorus	0.44

REFERENCE: H. Fréchette, Mines Branch, Summary Report, 1909, p. 83.

Fahey Mine.—The Fahey mine is located on lot 26, concession XI, about 1,000 feet east of White lake. The workings consist of a shaft 20 feet deep, and a few trenches, all of which are on a hematite vein. The ore deposit is exposed in one place from wall to wall, showing a width of 15 feet. Both walls are crystalline limestone. A sample from an ore pile gave the following analysis:—

	Per cent.
Iron	34.73
Insoluble	2.44
Sulphur	0.054
Phosphorus	0.029
Lime	20.30
Magnesia	3.44
Manganese	0.32

REFERENCE: H. Fréchette, Mines Branch, Summary Report, 1909, p. 82.

TOWNSHIP OF DALHOUSIE

Playfair or Dalhousie Mine.—The Playfair mine is situated on lot 1, concession IV. The mine was opened in 1866, and between 1866 and 1871 it is reported that 11,100 tons of good ore were shipped to United States points.

The ore deposit was a lens-shaped body of hematite which showed a tendency to thin out both in length and depth. The total length of the excavation was about 500 feet, and for about half the distance at the eastern end the main body was paralleled by a smaller one, the two being separated by a wall of limestone 5 to 10 feet in thickness. The greatest thickness of the smaller lens was about 7 feet, and it seems to have thinned out to nothing both in length and depth. The enclosing country rock is crystalline limestone.

The following analysis by the Geological Survey gives the composition of the ore:—

	Per cent.
Iron	57.6
Insoluble	16.05
Phosphorus	0.026

REFERENCE: E. D. Ingall, Geological Survey of Canada, Vol. XII, p. 70-I.

TOWNSHIP OF SOUTH SHERBROOKE

Bygrove Mine.—The Bygrove mine is located on lot 3, concession I. The only development work done at this place consists of a pit about 40 feet long by 20 feet wide and 25 feet deep. The pit is now full of water to within 10 feet of the top.

The ore to be seen in the walls of the upper parts of this pit, consists of magnetite in irregular and apparently not very persistent ribs, varying from an inch or two to a little over a foot in thickness. They thin out rapidly in some places, while in others they enter in a very erratic manner. Blasts put into the outcrop along a length of about 50 feet show magnetite occurring in the same irregular way as in the pit. Pyrite is present but not in very large quantities.

To the south of the pit for some distance there is a considerable development of acid gneiss. To the northward definite outcrops of solid rock are infrequent; there are, however, no signs of limestone for some distance. The walls of the pit show rather rotten brownish gneissic rock.

REFERENCE: E. D. Ingall, Geological Survey of Canada, Vol. XII, p. 32-I.

Fournier Mine.—The Fournier mine is located on lot 14, concession I. The workings consist of five pits and other openings. The ore is magnetite, and the deposits are found in an area of dark-coloured basic gneiss. The mode of occurrence is in irregular ribs, veins, and pockets. Apparently the proportion of ore recoverable from the tonnage of material extracted was too small for economic operations.

The last attempt at operation was made in 1873 when a shaft was sunk 110 feet, and about 600 tons of good ore were raised. No analyses of the ore are available.

Magnetic readings taken systematically with the dip needle, showed magnetic disturbance only in the immediate vicinity of the pits, or at those points where ore was already known to exist.

REFERENCE: E. D. Ingall, Geological Survey of Canada, Vol. XII, p. 34-I.

Christie Lake Mine.—This property comprises lots 18, 19, and 20, concession III, on the north shore of Christie lake.

The country rock is a dark-coloured gneiss through which magnetite occurs disseminated in small grains and concentrated in small pockets and long narrow lenses. The greatest thickness of ore reported is 7 feet, and the greatest length 200 feet.

A number of dip needle readings were taken, and these showed magnetic disturbances only in the immediate vicinity of the pits.

Analyses of four samples taken in 1906 by W. S. Johnson are given herewith:—

	Stripping No. 1 per cent.	Stripping No. 2 per cent.	Stripping No. 3 per cent.	Stripping No. 4 per cent.
Iron	60.57	61.32	60.29	59.13
Sulphur	4.47	0.12	0.206	0.55
Phosphorus	0.004	0.008	0.009	0.003
Titanium dioxide	0.87	1.74	1.39	1.04

REFERENCES: E. D. Ingall, Geological Survey of Canada, Vol. XII, p. 37-I.
W. S. Johnson for D. W. Ogilvie and Company, Montreal, Que., 1906.

Silver Lake Mine.—On lot 16, concession IV, on the east shore of Silver lake, there are two pits with several shallow workings between, known locally as Silver Lake mine.

The main or more northerly pit is a small cut made in a dark, compact hornblende rock, and very little magnetite is to be seen in place.

The second pit is about 100 yards south from the main pit. Here an exposure of dark crystalline hornblende, reticulated with ribs and veins of magnetite, occurs.

Dip-needle readings showed strong attraction south of the main pit. Between it and the southern pit there are some evidences of one or two possible occurrences of magnetite. Elsewhere no attraction out of the normal was found.

REFERENCE: E. D. Ingall, Geological Survey of Canada, Vol XII, p. 41-I.

Ritchie Mine.—On lot 16, concession VII, are some workings known as Ritchie mine. A small test pit shows magnetite in narrow bands at the north and south ends. The ore bands apparently follow the strike of the enclosing gneissic rock and dip to the south. Both here and at another pit the magnetite is mixed with gangue matter comprising calcite, mica, hornblende, etc. A picked specimen of magnetite had an iron content of 67.6 per cent., but the average percentage of iron in any considerable tonnage would be low.

REFERENCE: E. D. Ingall, Geological Survey of Canada, Vol. XII, p. 42-I.

Morran Mine.—The Morran mine is located on lot 13, concession VIII, about 1 mile distant from the Ritchie mine.

The country rock is a dark-coloured gneiss containing small pockets and disseminations of magnetite. Apparently no quantity of interest of merchantable ore was exposed in the workings.

The following is the analysis of a picked specimen of ore reported to have come from this lot:—

	Per cent.
Iron	68.43
Silica	2.79
Sulphur	0.067
Alumina	0.189
Magnesia	0.38
Manganese	0.26

Magnetite of similar grade and of similar mode of occurrence outcrops frequently for a distance of 2 miles to the west.

REFERENCES: E. D. Ingall, Geological Survey of Canada, Vol. XII, p. 43-I.
A. B. Rudd, Perth, Ont., 1914.

TOWNSHIP OF BATHURST

Lots 10 and 11, concession VIII, are known as the *Foley Mine* property. The property was operated years ago when apparently all the ore exposed was removed.

As far as could be ascertained, the deposits consisted of an aggregate of magnetite, hornblende, apatite, and pyrite.

REFERENCE: E. D. Ingall, Geological Survey of Canada, Vol. XII, p. 45-I.

17. County of Leeds

TOWNSHIP OF NORTH CROSBY

The *Matthews mine* is located on the north shore of Mud lake, on lot 1, concession VI, about 1 mile from the village of Newboro on the Brockville division of the Canadian National railway. Shipping facilities by the Rideau canal, of which Mud lake forms a link, are also available.

The ore bodies consist of irregular segregations of titaniferous magnetite in a coarse-grained gabbro-gneiss. A magnetometric survey indicated the existence of a considerable quantity of ore to the south and southwest of the ore body, which was exploited by a pit 300 feet long and 100 feet wide.

Mining operations date from 1860. During 1871 upwards of 4,000 tons of ore were raised, of which 3,300 tons were shipped via boat to Cleveland, Ohio. There is no information available concerning any operation subsequent to that time.

REFERENCES: E. D. Ingall, Geological Survey of Canada, Vol. XII, p. 66-I.
B. F. Haanel, Mines Branch, Summary Report, 1909, p. 112.

The *Allan prospect*, on lot 27, concession IV, shows magnetite in small veins and ribs in a dark basic rock.

Dr. T. S. Hunt analysed a specimen of ore from the Allan property with the following result:—

	Per cent.
Magnetic oxide of iron	90.14
Alumina	1.33
Lime	0.82
Magnesia	0.84
Insoluble	5.25
Phosphorous	0.007
Sulphur	0.12

The percentage of metallic iron was 64.90. The insoluble residue was chiefly white quartz with a little black mica and green pyroxene. The specimen is described as "bright crystalline magnetite, free from any visible pyrites but containing some sulphur."

REFERENCE: E. D. Ingall, Geological Survey of Canada, Vol. XII, p. 36-I.

TOWNSHIP OF SOUTH CROSBY

The *Chaffey mine* is located on an island in Mud lake, which is part of lot 27, concession VI. It is about half a mile south of the Matthews mine. Shipping facilities are available over the Canadian National railway, passing within a mile of the property, and via the Rideau canal to the Great Lakes.

As at the Matthews mine, the ore is a titaniferous magnetite, and the ore bodies seem to be isolated, irregularly-shaped segregations in a coarse basic rock, probably gabbro. Three ore bodies have been exploited by open pits, probably quite thoroughly. A magnetometric survey indicates the existence of some ore unexplored as yet.

The following is an analysis by the Geological Survey of Canada, of Chaffey Mine ore:—

	Per cent.
Iron	50.23
Silica	7.10
Sulphur	1.52
Phosphorus	0.085
Alumina	5.65
Titanium dioxide	9.80

The mine was operated in 1858 and 1859, during which time about 6,000 tons of ore were shipped to Pittsburg, Pa. Shipments in 1870 and 1871 to Cleveland, Ohio, were of apparently about 11,000 tons. Of operations subsequent to 1871 there is no information available.

From the early reports of the Geological Survey, it appears that the Chaffey iron ore deposit had been visited by Sir W. E. Logan prior to 1851. In that year his assistant, Alexander Murray, visited the locality, and in a report dated at Woodstock, January 29th, 1852, Mr. Murray states that he examined the iron ore deposit on the 26th lot of the 6th concession of South Crosby "where on an island in Mud lake not far from Newboro on the Rideau canal, and near the crystalline limestone in the vicinity, a mass [of magnetic iron ore] of considerable purity running north-east and southwest, and apparently coinciding with the stratification, has a breadth of seventy yards. . . . The great supply of ore that might be here obtained, the proximity of wood in abundance for fuel, and the existence of water power at no great distance combined with the advantage of a navigable canal, the water of which is in contact with the ore, render the locality

well worthy of attention, of such as are disposed to attempt the smelting of iron ore in the Province." No smelting was attempted here; but mining of ore for export to the United States began a few years after Murray's report was published.

About this time Messrs. Forsyth & Company, operators of a smelter at Pittsburg, were bringing magnetic iron ore from a mine in Quebec down the Rideau canal to Kingston for shipment to their smelter. Messrs. Chaffey of Kingston were interested in the transportation of the ore, and it was they who in 1858 opened up the deposit at Newboro which then became known as the Chaffey mine. As the ore could be loaded directly from the mine onto the barges on which it was carried to Kingston, the cost of transportation was low. The ore was highly titaniferous, but a considerable quantity was sold. The first shipments went to Pittsburg, via Cleveland. The Chaffey brothers stocked a supply of ore at Kingston and offered it for sale there at about $3.00 per ton.

Development of the Matthews mine, a short distance from the Chaffey, was also begun by the Chaffey brothers. In the early reports of the Geological Survey, the combined production of the two mines for the years 1870 and 1871 is given as 14,250 tons. From the size of the open workings on the properties, it is probable that there was much more ore taken out than there is any record of.

According to Mr. E. D. Ingall who visited the mine about 1895, there were then at the Chaffey mine several pits, partly filled with water, and three of these were about 150 feet long, 50 feet wide at the surface, and were said to be about 50 feet deep.

According to Dr. T. Sterry Hunt, considerable quantities of the ore shipped were used in puddling furnaces at Pittsburgh and Chicago. Dr. Hunt states that the ore contained more or less sulphur in the form of small grains of pyrites. His analysis of a sample of the ore is given above. Another analysis by Dr. A. A. Hayes showed 1.49 per cent. sulphur and 16.45 per cent. titanium dioxide.

In a report dated May, 1874, Dr. B. J. Harrington says that the annual production of the Matthews or Yankee mine and the Chaffey mine together "for several years has been between 7,000 and 8,000 tons." He states further that "were the demand for titaniferous ores greater, the production could be greatly increased." An analysis of the ore by Dr. Harrington showed 12.32 per cent. titanic acid and also considerable sulphur.

In a tabulated statement of the mineral production of Canada for the years 1869 to 1871, inclusive, Mr. Charles Robb gives the combined production of the Matthews and Chaffey mines for this three year period as 22,720 tons, valued at $56,800.

REFERENCE: E. D. Ingall, Geological Survey of Canada, Vol. XII, p. 66-I.

PART III.

BIBLIOGRAPHY

1. Reduction of Iron Ores by Processes Other than the Blast Furnace Process

A.—IRON ORE REDUCTION IN ELECTRIC FURNACES

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Describes the furnaces in use for the electrometallurgy of iron up to 1907.

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The furnace used was a simple, short-shaft furnace, lined with various refractory materials, such as bottom of carbon to act as one electrode, and sides partly of carbon and silica brick or magnesite brick. The upper prismatic electrode was carbon. Tables show the conditions of the nineteen experiments and a brief summary of the results of each is given.

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Redogörelse för vid Domnarfvets järnverk gjorda försök att i elektrisk ugn framställa järn ur järnmalm. (The electric shaft furnace at Domnarfvet, Sweden.) 1909. (Beihang till Jernkontorets Ann., 1909, pp. 739-774; Met. and Chem. Eng., vol. 8, pp. 11-17.)
Describes the experiments at Domnarfvet, giving furnace design, analysis of charges, etc. The advantages of the electric shaft furnaces over the blast furnace are as follows:—

1. Lower installation cost, since blowing engines and heating apparatus are not required.
2. Saving of about two-thirds of the fuel.
3. Ore dust can be used without briquetting.
4. The generated gases have a high heat value when free from nitrogen.
5. Possibility of producing low carbon iron.
6. Less attendance.

According to an estimate made the coke consumption was about 5 cwts. 3 grs. per ton of pig iron.

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the heating chamber. A damper permits of direct passage to atmosphere when desired. Carbon in the form of charcoal is contained in a hopper and fed alternately with the iron ore and lime mixture. The ore used is a high-grade magnetite, averaging 68 per cent. of iron, and very low in sulphur and phosphorus.

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Reference is made to alleged discrepancies between the official figures of the cost of smelting ore published by the Norwegian Departmental Electrometallurgical Committee and the Swedish Committee of Experts. The Swedish committee states that the result of trials in Sweden show that coke as a reduction material has been found unsuitable. They state also that a higher sulphur content is obtained in the electric smelting furnace than that in the iron produced in the ordinary blast furnace. The Norwegian committee held the opposite view of these matters.

EVANS, J. W.
Tool steel from titaniferous magnetite by Evans-Stansfield electric furnace process. 1912. (Trans. Can. Min. Inst., vol. 15, pp. 123-128; abst., Jour. Iron and Steel Inst., vol. 87, pp. 600-601.)
Describes a furnace of a capacity of more than a quarter of a ton of steel per 24 hours. The furnace has a tower preheater. Experiments indicate that in a five-ton furnace the cost of steel will not be more than 3 cents a pound. Steel of any required carbon content can be made by regulating the quantity of carbon used in the briquettes, which are used as a charge.

Kershaw, J. B. C.
Electric furnace methods of iron production. 1912. (Iron Tr. Rev., vol. 50, pp. 41-46.)
Describes the types of furnaces in use for electric iron ore smelting, giving diagrams of each.

Leffler, J. A., and Nyström, E.
Electric furnace pig iron at Trollhättan. 1912. (Met. and Chem. Eng., vol. 10, pp. 413-416.)
Abstract of the report to the Jernkontoret of Sweden, covering the working of the furnace from August 4th, 1911, to March 6th, 1912. The system of gas circulation with its limitation on the economy of the fuel gives a temporary advantage but sets a sharp limit on future reduction of fuel consumption. The question is still in an experimental stage.

Leffler, J. A., and Nyström, E.
Progress of electric iron smelting. 1912. (Iron and Coal Tr. Rev., vol. 84, p. 996.)
Describes progress of electric iron smelting at Trollhättan, Sweden. The carrying over of dust by the gas has been stopped by the use of a scrubber. The waste of electrodes has been reduced by the adoption of round electrodes, 2 feet in diameter, which are arranged for joining up to one another by means of a screw nipple. The lower end of the shaft opening into the hearth was increased from 1,200 to 1,300 millimeters. In addition the hearth of the furnace was relined. The furnaces were not designed for coke and its use was not very satisfactory, but other furnaces designed for coke have proved that this fuel is suitable for electric smelting. Ten furnaces are completed or are in process of construction.

Neumann, Bernhard.
Neure Ergebnisse der elektrischen Roheisenerzeugung auf dem Versuchswerk am Trollhättan. (Recent results in electric production of cast steel at the Trollhättan experimental plant.) 1912. (Stahl und Eisen, vol. 32, pp. 1409-1416.)
Gives tables showing analyses of charges, amount of energy used; analyses of slag, pig iron, and circulation gases.

Nicou, Paul.
La production de la fonte au four électrique en Suède. (The production of cast iron in electric furnaces in Sweden.) 1912. (Rev. de Mét., vol. 9, pp. 209-252; Rev. Univ. des Mines, ser. IV, vol. 37, pp. 127-184.)
Describes the Trollhättan plant and results of its works. Gives numerous tables showing the working of the furnaces, estimates of the cost, analyses of the materials employed and of the charges, the pig iron produced, the slags, and the gases. The results were highly favourable to the process employed.

The production of pig iron in the electric furnace. 1912. (Elec. Rev., London, vol. 71, pp. 44-45.)
Covers experiments for six months' period at Trollhättan.

Rice, S.
Experiments in electrical smelting of iron ores. 1912. (Min. and Eng. World, vol. 36, pp. 811-814.)
Gives theoretical calculations for electric smelting and describes some experiments in an electric shaft furnace.

Richards, J. W.
Electric furnace production of pig iron and pig steel. 1912. (Proc. Eng. Soc. Western Pennsylvania, vol. 28, pp. 83-116.)
Describes the work in Sweden, giving data on power consumption, electrode consumption, circulation of the gases, the nature of the product, etc.

Richards, J. W.
Gas circulation in electrical reduction furnaces. 1912. (Trans. Am. Electrochem. Soc., vol. 21, pp. 403-407; disc., pp. 407-417; Met. and Chem. Eng., vol. 10, pp. 289-290.)
Concludes that the arch of the crucible of the furnace should be protected by water-cooled plates as in open hearth furnaces, that the artificial circulation of the gas in the furnace should be dispensed with, that the limestone flux should be calcined before putting into the furnace, that the shaft of the furnace should be provided with auxiliary heating to maintain the contents at or above 400°C., to permit of reduction of Fe_2O_3 by the slow current of CO gas. Under these conditions an amount of carbon equal to one-fifth of the weight of iron produced should be sufficient. If circulation were eliminated and the amount of fuel reduced the operation would be cheapened.

ROBERTSON, T. D.
Iron and steel smelting in Electro-Metals furnaces. 1912. (Electrician, London, vol. 70, pp. 501-505.)
Briefly describes Swedish practice.

ROBERTSON, T. D.
Recent developments in electric iron smelting. 1912. (Applied Sci., vol. 5, pp. 138-148.)
Describes Swedish practice and refers to the experiments at Sault Ste. Marie.

THORNE, C. A., FARUP, P., and VOGT, J. H. L.
Elektrisk Jernmalmsmeltning. (Electric iron ore smelting.) 1912. (Teknisk Ugeblad, vol. 30, pp. 592-593; Min. Jour., vol 99, pp. 1120, 1145-1146; abst., Jour. Iron and Steel Inst., vol. 87, pp. 594-595.)
With reference to the differences in cost of smelting in Sweden and Norway these authors point out that the Swedish electric iron ore smelting furnaces were especially constructed for the use of charcoal, whereas the furnace at Hardanger was designed for the employment of coke. No complaint has been received concerning the use of coke, and pig iron practically free from sulphur can be produced by the electro-thermal process. The iron therefore does not require to have a high percentage of silicon.

VAN NORDEN, R. W.
Electric iron smelter at Héroult on the Pitt. 1912. (Jour. Elec. Power and Gas, vol. 29, pp. 453-459.)
Describes electrical and charcoal plants as well as the electric smelter of the Noble Electric Steel Company.

1913—BEIELSTEIN, A.
Neueres aus der Elektro-Roheisenerzeugung Skandinaviens. (New developments in the electric production of pig iron in Scandinavia.) 1913. (Stahl und Eisen, vol. 33, pp. 1270-1278; abst., Jour. Iron and Steel Inst., vol. 88, pp. 585-596.)
Discusses the economy of electric pig iron production in Scandinavia. By the method there used the ore, intimately mixed with fuel, is hand fed into the electric furnace. Air is not allowed to enter, consequently the gases evolved by the reduction of the ore are richer in carbon monoxide than blast furnace gases and contain no nitrogen. In fact the carbon monoxide may amount to 90 per cent., so that the calorific value and the reducing power of the gases are abnormally great.

CRAWFORD, JOHN.
Progress of electric smelting at Héroult, Calif. 1913. (Met. and Chem. Eng., vol. 11, pp. 383-388; abst., Iron Age, vol. 92, pp. 124-126.)
Gives an account of the progress made at the plant of the Noble Electric Steel Company up to the building of the 2,000-kw. three-phase furnace of the long and narrow type which has four electrodes delta-connected and suspended between five charging stacks. Charcoal is used as fuel. The charging unit is 500 pounds of ore.

Electric iron smelting at Hardanger. 1913. (Min. Jour., vol. 102, pp. 863-865, 885-887.)
Gives tables showing production from November, 1911, to March, 1913. The various ores used at Hardanger are described, including Koldeberg piece ore, Rodsand slag, Sydvaranger briquettes, Persberg piece ore, and also the limestone. The figures for gas production and coke, electrode and power consumption, are contained in tables.

Electric iron smelting at Trollhättan, Sweden. 1913. (Iron and Coal Tr. Rev., vol. 86, p. 744.)
Gives report of research work. It has been found that the proportion of concentrates ought not to exceed 20 per cent. of the ore charged. Gives data concerning power consumption, charcoal consumption, electrode consumption, cost of repairs, and quality of pig iron.

FORNANDER, E.
Electric iron and steel production at Hygfors in Sweden. 1913. (Iron and Coal Tr. Rev., vol. 86, p. 955.)
The furnaces are of the Elektrometall type, each having a capacity of 3,000 horsepower. They have six electrodes instead of four, and these are cylindrical with the screw-thread arrangement.

Foundry pig iron smelted in electric furnaces. 1913. (Iron Tr. Rev., vol. 53, pp. 493-497.)
The ore smelted at Héroult, Calif., is magnetite. The furnaces are long and narrow, each having four electrodes delta-connected and suspended between five charging stacks. Charcoal is used for fuel.

Hanson, H. J.
Smelting iron electrically with coke as fuel. 1913. (Iron Tr. Rev., vol. 53, pp. 1003-1007.)
The Tinfos Iron Works at Notodden, Norway, use coke to smelt the 44 per cent. magnetite ore. The amorphous carbon electrodes are described and a cross-section of one of the electric furnaces is given.

Kershaw, J. B. C.
Electro-thermal methods of iron and steel production, 1913, London, Constable and Co. Ltd., pp. 239.
Pp. 20-42: describes various types of furnaces for electric smelting of iron ores.

Louvrier, Francis.
A new type of electrical furnace for the reduction of ores. 1913. (Met. and Chem. Eng., vol. 11, pp. 710-713.)
Describes the Louvrier-Louis furnace for the reduction of ores. The electrodes are practically fixed, and the regulation of the temperature is accomplished by the simple manipulation of switches, by means of which the number of electrodes in circuit or the position which they occupy towards each other can be varied. The consumption of electrical energy in treating 50 per cent. ore should not exceed one-quarter horsepower year per ton of pig iron produced, and would be reduced to one-fifth horsepower year when the carbon monoxide is burnt inside the furnace. It is claimed that outputs as large as blast furnace outputs could be obtained in such a furnace.

Lyon, D. A.
Electric furnace in the production of iron from ore: discussion of present status and comparison of Scandinavian and Californian practices. 1913. (Met. and Chem. Eng., vol. 11, pp. 15-19.)
The California practice differs from the Swedish in that there is no attempt at reduction in the stacks of the furnace, there is no circulation of gases, and the limestone used is calcined outside the furnace.

Nicou, Paul.
Le haut fourneau électrique. (The electric blast furnace.) 1913. (Bull. Soc. de l'Ind. Min., ser. V, vol. 3, pp. 589-623; Ann. des Mines, ser. II, vol. 3, pp. 133-249, 255-352.)
Describes electric smelting of pig iron in Sweden giving details of the charges, the consumption of energy, the conditions of working, and the ultimate product, together with sketches of the furnaces. Describes experiments at Sault Ste. Marie. Believe that greater economy would be obtained using electric blast furnaces on a larger scale. Describes fully the experiments carried out at Trollhättan under the auspices of the Jernkontoret.

Odquist, Gustav.
The present position of electrical smelting of iron ore in Norway, 1913. (Iron and Coal Tr. Rev., vol. 87, p. 992.)
Discusses the failure of the attempts to smelt iron ore at Hardanger. Does not consider the furnace suitable for coke. There is also some trouble with the electrical plant. In addition, the ore used was too poor. The reason why the Elektrometall furnace could not be worked on an economical basis with coke was the greater variation of the electrical resistance in the furnace itself when coke was used, which affected the average load and reduced the production.

Orten-Boving, J.
Electric iron smelting. 1913. (Can. Eng., vol. 25, pp. 877-880; Iron Age, vol. 93, pp. 1268-1270.)
Describes recent developments in production of pig iron in the furnace of the Elektro-Metals, Limited, in Sweden. The furnaces have six electrodes, cylindrical in shape and arranged to be used continuously without waste by screwing the ends together. Charcoal is used as fuel. Pig iron has been made for open hearth treatment, for Lancashire treatment, for Bessemer treatment.

The present state of the electrical smelting industry. 1913. (Iron and Coal Tr. Rev., vol. 86, p. 537.)
Table gives comparison of results between work at Domnarfvet and Trollhättan iron works as to average load, pig iron per kw. year, charcoal and electrode consumption.

Rodenhauser, W.
Fortschritte im Bau und Betrieb elektrischer Höchofen. (Progress in construction and working of the electric shaft furnace.) 1913. (Elektrische Kraftbetriebe und Hahnen, vol. 11, pp. 561-566; abst., Jour. Iron and Steel Inst., vol. 89, p. 650.)
Gives a general account of the progress in the construction and working of electric shaft furnaces for smelting iron ore. The use of such furnaces is at present limited to those countries which have high-grade ores, cheap electric supply, and where charcoal is readily obtainable.

1914—BEIELSTEIN, A.
Zur Stillegung des Hardanger Elektrohochofenwerks. (The shutting-down of the Hardanger electric smelting plant.) 1914. (Stahl und Eisen, vol. 34, pp. 1172-1175; abst., Jour. Iron and Steel Inst., vol. 90, p. 324.)
Reviews the causes which led to the shutting-down of the Hardanger electric smelting plant in 1913. The failure is attributed mainly to the use of coke containing 0.8 to 0.9 per cent. of sulphur, which necessitated a considerable addition of lime and a corresponding increase in the current consumption. Trials were made with four different kinds of ore, the best results being obtained with Sydvaranger briquettes containing 91.3 per cent. of ferric oxide. The charge was made up of 71.9 per cent. of Sydvaranger briquettes, 9.5 per cent. Rödsand slag, and 18.7 per cent. of lime, the coke consumption being one-third of a ton per ton of pig iron yielded. The current consumption was 3,206 kilowatt-hours per ton of pig iron.

DALTON, A. C.
Electric steel direct from ore fines. 1914. (Iron Age, vol. 94, pp. 877-879.)
Describes the process at the plant of the Moffat-Irving Steel Works, Ltd., of Toronto, Canada. The furnace is of the 300-kilowatt, three-phase type; the electrodes are of graphite, cylindrical in shape. The ore used was blast furnace flue dust, air-slacked lime was used as a flux, and coke breeze for carbon. The success of the process opens a new field in the use of low-grade ore after concentrating without the further expense of briquetting.

Electric furnace for pig iron. 1914. (Iron Tr. Rev., vol. 55, pp. 521-522.)
Describes the large Helfenstein furnace in operation at Domnarfvet, Sweden. Photographs show the exterior of the furnace, the charging floor and electrodes.

Electric iron smelting, 1914, A/B. Elektrometall, Ludvika, Sweden; and Electro-Metals, Ltd., 9½ Union Court, Old Broad Street, London, E.C.

Electro-thermic iron ore smelting in Norway. 1914. (Eng. and Min. Jour., vol. 98, pp. 158-160.)
Discusses reasons for economic failures of electric smelting at Hardanger. The smelters at Tinfos and Ulefos and the Helfenstein furnace are discussed briefly.

FORSBERG, G. A.
Förslag till kombinering av en elektrisk ugn och en lancashire härd. (Trials with a combination of an electric furnace and a Lancashire hearth.) 1914. (Beihang till Jernkontorets Ann., 1914, pp. 36-38; abst., Jour. Iron and Steel Inst., vol. 91, p. 557.)
Gives an account of some preliminary trials made of a combination of an electric furnace and a Lancashire hearth. Owing to faulty arrangements the trials were not carried on, but from the results obtained, the author is confident that in smelting small pig he could effect a saving of at least 10 hecto litres of charcoal per ton. Complete plans of a suggested installation are given.

HARDEN, JOH.
The electric iron smelting at Hardanger. 1914. (Electrician, London, vol. 72, pp. 766-771, Met. and Chem. Eng., vol 12, pp. 82-86, 223-225, 444-446.)
Deals with the unsatisfactory results that have been obtained from the electric smelting at Hardanger. The choice of a reduction agent is first discussed, and it is then shown that the defective nature of the electrical equipment had a large share in rendering the trials a failure. The effect of discarding gas circulation in the furnaces from this cause and the suitability of various kinds of ore for electric smelting are then dealt with. Concludes with an account of electrode consumption.

HELFENSTEIN, A.
A large electric furnace for pig iron. 1914. (Foundry Tr. Jour., vol. 16, pp. 269-271.)
No shaft is employed in the Helfenstein furnace. The operation and construction of the furnace is given.

HELFENSTEIN, A.
Large electric furnaces for pig iron. The Helfenstein furnace at Domnarfvet. 1914. (Iron and Coal Tr. Rev., vol. 88, pp. 505-506.)
The Helfenstein furnace has no shaft. With charcoal the consumption of energy per ton of pig iron was 2,000 kilowatt hours, consumption of charcoal was 6 to 8 hundredweights per ton of pig iron, and the consumption of electrodes was 15½ pounds. A pulverized ore can be used without any trouble.

HUMBERT, E., and HETHEY, A.
Production of steel direct from ore. 1914. (Jour. Iron and Steel Inst., vol. 89, pp. 378-395; Iron Age, vol. 93, pp. 1230-1232; Engineering, May, vol. 47, pp. 583-586; Feuerungstechnik, vol. 3, pp. 129-131.)

Describes experiments made in a normal Héroult electric furnace of 6-ton capacity and working with single-phase current. Tests were made on Swedish and Brazilian ore. The outstanding quality of steel produced by this process is its toughness. Nitrogen and hydrogen are not introduced by this process which constitutes a distinct advantage.

KEENEY, R. M.
Fluorspar in electric smelting of iron ore. 1914. (Min. and Sci. Press, vol. 109, pp. 335-336.)
In making pig steel an excess of fluorspar caused an increase of carbon in the pig steel. A small quantity of fluorspar assists materially in the production of a fluid basic slag.

KEENEY, R. M.
Pig steel from ore in the electric furnace. 1914. (Am. Inst. Min. Eng., Bull. 86, pp. 349-367; disc., Bull. 90, pp. 1289-1296; abst., Iron Age, vol. 93, pp. 810-812.)
Deals with the general principles involved and concludes that carbon can be kept below 2.2 per cent. in the product if a fair grade of ore is used, that it is not difficult to slag the greater part of the silicon, phosphorus, and sulphur of the charge, if the furnace is hot and the slag fluid. The loss of iron in the slag should not be excessive unless the pig steel is of very low carbon content. Results obtained at Domnarfvet, Trollhättan, and Héroult indicate no great difficulty in producing pig steel in an electric shaft furnace. Believes if there is a market for steel that it is more economical to produce pig steel than pig iron.

LANGENDONCK, C. VAN.
The Helfenstein large electric furnace. 1914. (Iron Age, vol. 94, pp. 478-480.)
The furnace was designed for the Domnarfvet Iron Works in Sweden and has a capacity of from 6,000 to 8,000 horse-power. The advantages of the large size are as follows:—
1. The capital expenditure is lower.
2. The furnace gases possess a greater valve.
3. The process can be better controlled.
4. A pulverized ore can be used.
5. Only seven men are needed to attend the furnace.
6. The furnace permits the use of coke as a reducing material.

LOUDON, T. R.
Electric smelting of Canadian iron ores. 1914. (Applied Sci., vol. 8, pp. 219-223; Can. Min. Jour., vol. 35, pp. 150-152.)
Describes the Moffat-Irving furnace which is of 300-kilowatt capacity, having 3 electrodes situated at equal intervals around the furnace and dipping into the crucible at about 60 degrees to the horizontal. The ore is crushed and finely ground; coke is used as fuel.

LYON, D. A., and KEENEY, R. M.
Electric furnace in pig iron manufacture. 1914. (U.S. Bur. Mines, Bull. 67, pp. 7-57.)
Describes the developments of electric smelting in Sweden and California and compares the two. Discusses the problems yet to be solved in electric smelting.

ODQUIST, GUSTAV.
Om den elektriska järnframställningen vid Hardanger elektriske jern-og stallverk. 1914. (Teknisk Tidskrift [Kemi och Bergsvetenskap], vol. 44, Feb. 25, pp. 24-25; abst., Jour. Iron and Steel Inst., vol. 91, p. 554.)
Results obtained at Hardanger in Norway have shown that coke can be used as a reducing agent in the type of furnace used there. With coke the electrode consumption is smaller, but an increase in current and a decrease in voltage are caused by the low resistance of the coke.

STANSFIELD, ALFRED.
The electric furnace, its construction, operation and uses, 1914, New York, McGraw-Hill, pp. 415.)
Pp. 173-211: constitutes a chapter on the production of pig iron in the electric furnace.
Pp. 250-264: describe the production of steel from iron ore.

The Tinfos electrical iron works. 1914. (Iron and Coal Tr. Rev., vol. 88, pp. 868-870.)
The ore used holds only 43 to 46 per cent. of iron. The furnaces have a capacity of 1,250 kilowatts each, and are constructed as single-phase furnaces with bottom and top electrodes. Coke is used as fuel.

1915—DALTON, A. C.
Electric steel direct from ore fines. 1915. (Iron Age, vol. 96, pp. 1184-1185.)
Describes experiments using Moose Mountain magnetite ore crushed to 200-mesh at the Moffat-Irving Steel Works, Toronto, Canada. A natural draft was used to prevent excess of carbon. Coal was used as fuel. A thin, hot, fluid slag is essential. The steels produced showed remarkable uniformity.

Electric pig iron in Norway; a new type of furnace using coke successfully—cost data. 1915. (Iron Age, vol. 95, p. 1120.)
The Tinfos electric furnace differs from the Swedish furnace in having a shaft on each side so that the ore is led on to the two square electrodes. The upper electrodes each consist of three or four smaller ones. The electric current proceeds from the electrodes through the charge, the slag, and the liquid pig iron, down to the bottom electrode. The furnace has no gas circulation and requires very little cooling water. Two sectional views of the furnace are given.

Electric steel direct from titaniferous ores. 1915. (Iron Age, vol. 96, p. 1416.)
Describes briefly the work of the Tivani Electric Steel Company at Belleville, Ont. A preheater is one of the interesting features. A 1-ton furnace has been operated for two months.

Electro-thermic iron ore smelting in Scandinavia. 1915. (Eng. and Min. Jour., vol. 100, pp. 351-352.)
The advantages of the shafts consist in the lesser consumption of coke and electric power, but the shafts give rise to a certain amount of trouble. Straight briquettes work poorly in the furnace. It is necessary to burn the limestone before use. Discusses the relative merits of coke and charcoal as fuel.

FARUP, P.
Proposed iron manufacture in Norway. 1915. (Iron and Coal Tr. Rev., vol. 90, p. 57.)
The use of coke as reducing fuel was found successful at Tinfos. The failure of Swedish furnaces in using coke was attributed to the narrow throats of the shaft and the arrangement of the electrodes.

LEFFLER, J. A.
Electric iron ore smelting in Sweden. 1915. (Engineering, vol. 100, pp. 131-133.)
Gives an account of the further development of electric iron ore smelting. The design of the furnace presents several new features. The bosh angle in the shaft has been increased to about seventy-nine degrees. At the bottom of the smelting chamber there is now placed a layer of closely-packed crushed coke or electrode fragments, and between the arch and the neck there is a water-cooled ring which serves as the terminus of the arch. The covering of steel plate on the top of the arch protects it against pressure from within. The circulation of the gas is maintained at a constant speed by fans. The smelting plant at Hagfors comprises three furnaces, a fourth being in course of construction.

NEUMANN, BERNHARD.
Stoff und Warmebilang des Elektro-Roheisenofens. (Economy of the electric pig iron furnaces in heat and material.) 1915. (Stahl und Eisen, vol. 35, pp. 1152-1158.)
A comprehensive study of the heat balance of the electric smelting furnace based on the data of the large Elektrometall furnace at Trollhättan and of smaller Swedish furnaces.

United States Consular Report, No. 260, Nov. 5, 1915, p. 521; abst., Jour. Iron and Steel Inst., vol. 93, p. 337.)
It is stated that an electric smelter at Belleville, Ont., is producing steel of all grades, including tool steel, direct from the ore. The heat of the waste gases of the smelter is utilized in a preheater. The plant has been working for about two months and has been using ore containing 7.5 per cent. titanium.

1916—GOSROW, R. C.
Coke as a reducing agent in the electric smelting furnace. 1916. (Met. and Chem. Eng., vol. 14, pp. 691-694.)
The nature of the physical properties most beneficial in a coke for such purposes is described, the effect of structure being especially considered. The conclusion is reached that although coke can be used under favourable conditions it is not, in general, a very satisfactory reducing agent.

STANSFIELD, ALFRED.
Electrothermic smelting of iron ores in Sweden. 1916. (Can. Dept. of Mines, Mines Branch, Rept. 344, pp. 65; abst., Engineering, vol. 122, pp. 5-6; Jour. Iron and Steel Inst., vol. 93, pp. 334-335.)
At present there are two types of electric furnaces for smelting iron ores: (1) the Elektrometall furnace in which the ore is preheated and partially reduced in a shaft before it reaches the smelting chamber; (2) furnaces of the Helfenstein, California, and Tinfos type in which the ore is not preheated. In Sweden the electric furnace has come into regular commercial use and the iron obtained from it is even better than from the charcoal-iron blast furnace, and the cost is somewhat less. Canadian ores do not approach the Swedish standard of purity, thus Swedish practice does not throw much light on electric smelting in Canada.

1917—Boving, J. O.
Electric iron smelting. 1917. (Iron and Coal Tr. Rev., vol. 94, pp. 601-602.)
Briefly summarizes Swedish practice.

Leffler, J. A.
The cost of electric pig iron production in North Sweden. 1917. (Engineering, vol. 104, pp. 621-623.)
Considers costs of electric power, fuel for reduction, and ore.

Leffler, J. A.
Am elektrisk tackjärnstillverkning i Norrland. (Electric smelting of iron ores in northern Sweden.) 1917. (Jernkontorets Ann., 1917, vol. 72, pp. 46-57; Iron Age, vol. 100, p. 605; Met. and Chem. Eng., vol. 17, p. 350; Iron and Coal Tr. Rev., vol. 95, p. 65.)
To smelt one metric ton of pig iron from the Luleä or Gellivare ores, 1.6 tons of ore and 0.4 ton charcoal are required and 0.272 kilowatt year of electric current. Gives a table of cost data. Such a low consumption of current can only be attained by installing four furnaces of a total of 9,000 kilowatts, one as a standby and three working continuously, as this would make it possible to utilize 92 per cent. of the purchased power.

Oesterreich, Max.
Helfenstein-Ofen in Domnarfvet. (The Helfenstein electric furnace at Domnarfvet, Sweden.) 1917. (Stahl und Eisen, vol. 37, pp. 1059-1063; Met. and Chem. Eng., vol. 16, pp. 509-510.)
Discusses the large Helfenstein electric furnace. The following average consumptions are given per ton of pig iron: Energy consumed (60 per cent. ore), 2,170 kw.-hr.; charcoal (70 per cent. C), 380 kg.; electrodes 5 kg. When working experimentally with coke the energy consumed was 2,600 to 2,700 kw.-hr., coke 310 to 330 kg. and electrodes 4 kg. Cranes have been provided for charging the furnace.

Stansfield, Alfred.
Electric smelting of titaniferous iron ores. 1917. (Eng. and Min. Jour., vol. 103, p. 1020.)
Believes magnetite could be smelted electrically near St. Charles, Que., for about $21 per ton.

Styri, H.
Electric furnace in the development of the Norwegian iron industry. 1917. (Trans. Am. Electrochem. Soc., vol. 32, pp. 129-140.)
Briefly describes the progress of electric pig iron manufacture in Sweden, stating some of the difficulties encountered in using various types of furnace.

Turnbull, R.
Electric pig iron in war times. 1917. (Trans. Am. Electrochem. Soc., vol 32, pp. 119-127; Iron Age, vol. 100, pp. 886-887, disc., p. 870; Iron Tr. Rev., vol. 61, pp. 828-829; Met. and Chem. Eng., vol. 17, pp. 459-460; Iron and Coal Tr. Rev., vol. 95, p. 671.)
Canadian experience showed that an ordinary electric smelting furnace with partial roof and automatic charging from overhead hoppers would produce a cheaper pig than the shaft furnace. Experiments were made using 50 per cent. each of scrap and ore in the charge, the result being an increased production from about 5 tons on ore alone to 11 tons with the mixture. The same amount of power was used in both cases.

1918—Escard, Jean.
La production électrothermique des fontes et aciers. 1918. (Rev. Gén. des Sci., vol. 29, pp. 366-373.)
The Noble Héroult furnace in operation at Sault Ste. Marie and the Trollhättan furnace are illustrated and described.

Grönwall, A.
Om elektrisk Järnmalmsmältning. (Electric smelting of iron ore.) 1918. (Teknisk Ugeblad, vol. 36, pp. 601-602.)
Gives results obtained at Hardanger.

1919—Bibby, J.
Developments in electric iron and steel furnaces. 1919. (Jour. Inst. Elec. Eng., vol. 57, sup. pp. 231-246; abst., Elec. Rev., London, vol. 84, pp. 136-137, 166-167, 176-177; Engineering, vol. 127, pp. 513-515; Electrician, vol. 83, pp. 214-217; Elec. World, vol. 74, pp. 84, 712-713; Iron Age, vol. 105, pp. 329-330; Jour. West of Scotland Iron and Steel Inst., vol. 27, pp. 21-29.)

Other things being equal the cost of blast furnace and electric smelting balance, when 1 horse-power year can be obtained for the price of 2.3 tons of coal. Analyzes the chemical action which takes place in the electric furnace. Describes methods of setting electrodes in reduction furnaces. Diagrams explain electrical connections.

Electric smelting in British Columbia. 1919. (Munic. Jour., vol. 125, pp. 262-263.)
Refers to the process of Trood and Darrah, in which the ore is crushed to a coarse powder, concentrated magnetically, the grains of ore converted into metallic iron by treatment at moderate furnace temperatures, and the grain metal then melted in electric furnaces. Estimates of cost for this process are included.

ESCARD, JEAN.
Fabrication directe, au four électrique, du fer et de l'acier à partir des minerais. (Direct production of iron and steel from the ore by means of the electric furnace.) 1919. (Rev. Gén. Elec., vol. 6, pp. 681-688.)
Discusses Stassano's experiments briefly and describes the process of Arnou. In this there are two zones in the furnace, one for reduction and one for melting. The experiments of Humbert and Heshey on the direct production of steel are described.

HASLER, O.
Die Herstellung von Haematit-Roheisen und Elektro-Stahl im elektrischen Schmelzofen. (Making hematite pig iron and electric steel in the electric furnace.) 1919. (Bull. Schw. Elektrotech. Verein, vol. 10, pp. 135-137.)
Gives table of cost of making hematite pig iron.

KEENEY, R. M.
Electric smelting with special reference to Canadian conditions. 1919. (Bull. Can. Min. Inst., Aug., pp. 846-853, Colo. Sch. Mines Mag., vol. 9, pp. 219-222; Min. and Eng. Rec., vol. 24, pp. 269-272.)
Believes that by the use of coal or charcoal as a reducing agent electric furnace pig iron should be made more cheaply in British Columbia than blast furnace pig iron. Lignite has been used in the electric smelting of manganese ores successfully, and it is possible it will be used for the reduction of iron ores.

SIMPSON, L.
Reduction of iron ores by the electrothermic process. 1919. (Bull. Can. Min. Inst., July, pp. 709-713.)
Gives a table of costs for the production of electrothermically reduced iron under conditions that can be found in Canada.

STANSFIELD, ALFRED.
Commercial feasibility of the electric smelting of iron ores in British Columbia. 1919. (Chem. and Met. Eng., vol. 20, pp. 630-636; abst., Bol. Mineria Chile, vol. 31, pp. 514-537; Eng. and Min. Jour., vol. 107, p. 224; Elec. Rev., vol. 74, p. 805.)
Discusses concentration of low-grade magnetites, the cost of electric current compared with coke and charcoal reduction, electrodes, types of furnaces, and the cost of plant and smelting.

1920—CASEY, G. L.
Smelting iron ore in an electric furnace. 1920. (Elec. Rev., N.Y., vol. 76, pp. 500-501.)
The furnace of the Smelters Steel Co. at Seattle, Wash., consists of a cylindrical crucible of boiler-plate steel, boshed at the base and lined with fire-brick. It is about 8 feet in diameter and 12 feet high, and the heat is centred in an amorphous carbon electrode, 14 inches in diameter, that stands in a vertical position. The ore is magnetite and coke is used as a reducing agent.

ESCARD, JEAN.
L'electrometallurgie du fer et de ses alliages, 1920, Paris, Dunod, pp. 811.
Pp. 1-114: discuss fully the electric smelting of iron ores, giving data on the various processes.

HORE, R. E.
Utilization of Ontario iron ores. 1920. (Can. Min. Jour., vol. 41, pp. 796-797.)
A process has been devised for reducing the ore in a fine state mixed with coke, in an air-tight retort heated externally by gas or fuel oil and then by the waste gases from the retort. The metallized product or sponge falls through a trap into an air-tight conveyor, which delivers it hot to the electric furnace. Gives an illustration of the plant. Mr. James W. Moffat devised the process.

JOHNSTON, R. C. C.
Prospects of electric smelting of iron in British Columbia. 1920. (Min. Jour., vol. 128, pp. 206-207; Iron and Steel Can., vol. 3, pp. 79-80.)

Describes the plant of the Vancouver Magnetite Iron and Steel Smelting Company, which has adopted the Fleet process. A simple long trough furnace is used, open at the top.

STIG, G.
Electric smelting of iron ore with coke. 1920. (Teknisk Ugeblad, vol. 66, pp. 151-153; Chem. and Met. Eng., vol. 23, pp. 29-31.)
Believes that in order to obtain good results economically with coke, only large furnaces should be used. Believes suitable changes will overcome difficulties of using coke in the Elektrometall furnaces.

Trattamento elettrotermico del minerale di ferro. (Electrothermal treatment of iron ore.) 1920. (Elettricità, vol. 53, pp. 18-20.)

1921—DE FRIES, H. A.
Electric reduction of iron ores; comparative costs for the commercial production of electric pig iron in the shaft and pit types of electric furnaces. 1921. (Chem. and Met. Eng., vol. 25, pp. 193-194.)
Concludes that if a lumpy ore and sintered concentrates are available, a large plant is desired, the demands of the central station are strict, and capital expenditure is of secondary nature, the electric shaft furnace should be employed. If only crude concentrates are available, or the plant depends on a varying ore supply, no objections being raised against single-phase loads, and capital expenditure has to be limited, then the pit furnaces apparently possess considerable advantages over the shaft type.

DE GEER, G.
Electric smelting of pig iron at Domnarfvet, Sweden. 1921. (Chem. and Met. Eng., vol. 24, pp. 429-433.)
Discusses the possibilities of using non-charcoal reducing agents and pit instead of shaft furnaces.

Electric smelting of pig iron in Sweden. 1921. (Iron and Coal Tr. Rev., vol. 102, p. 461.)
A mixture of equal parts of coke and charcoal has proved satisfactory as a reduction material. The shaft furnace seems to be superior to the open hearth electric furnace in running costs and output.

GUEDRAS, M.
Il problema della fabbricazione della ghisa al forno elettrico. (Manufacture of pig iron in the electric furnace.) 1921. (Giorn. Chim. Ind., vol. 3, pp. 104-105.)
Discusses production of gas in electric smelting.

HELFENSTEIN, A.
Die Zunkunft der elektrothermischen Eisengewinnung. (The future of electrothermic iron smelting.) 1921. (Stahl und Eisen, vol. 41, pp. 1481-1487, 1572-1576; disc., vol. 42, pp. 460-467.)
Considers the conditions under which it becomes economically possible to smelt iron electrothermically.

HERLENIUS, J.
Swedish electric pig iron furnace. 1921. (Chem. and Met. Eng., vol. 24, pp. 108-112.)
Gives briefly the details of construction of the Domnarfvet furnace, its method of starting and operation. Gives operating figures for a long campaign in 1920.

HODSON, F.
Electric smelting of iron ore. 1921. (Chem. and Met. Eng., vol. 25, pp. 881-882; Elec. World., vol. 78, pp. 25, 826-827; Iron Tr. Rev., vol. 69, pp. 1492-1493.)
Believes direct smelting in electric furnaces using cheap, water-generated power will probably within the next few years open up methods of utilizing vast supplies of iron ore which are at present almost worthless. The Swedish Elektrometall process has proved satisfactory for producing low silicon pig iron. Refers to the Japanese process for treating iron sand, to the Greaves-Etchells process, and to the Basset process.

LEFFLER, J. A.
Den elektriska tackjärnstillverkningens nuvarande standpunkt i Sverige. (Electric pig iron production in Sweden.) 1921. (Teknisk Tidskrift, vol. 51, April 27, pp. 59-71.)

PAGLIANI, S.
Sulla riduzione elettrotermica dei minerali di ferro e delle ceneri di pirite. (Electrothermal reduction of iron ore and pyrite ashes.) 1921. (Forno Elettrico, vol. 3, Dec. 15, pp. 164-168.)

Describes various electric furnaces, giving special attention to the Guédras furnace. Chemical reactions occurring in the furnace are discussed.

PRING, J. N.
The electric furnace, 1921, London, Longmans, Green and Co., pp. 485.
Pp. 162-194: section X discusses electric smelting of iron ores.

1922—DORNHECKER.
Uber die Entwickelung der italienischen Eisenindustrie durch weit gehende Anwendung elektrischer Energie im Schmelzbetrieb. (Development of the Italian iron industry by the extensive use of electricity in smelting.) 1922. (Stahl und Eisen, vol. 42, pp. 845-848.)
Describes the Fiat electric furnace.

DURRER, R.
Smelting iron ore electrically. 1922. (Stahl und Eisen, vol. 41, pp. 753-757; Iron Tr. Rev., vol. 70, pp. 827-828.)
Compares operating conditions in the standard blast furnace and the electric furnace. Gives causes of hot and cold working and discusses the relation of direct and indirect reduction in the electric furnace.

Electric smelting of pig iron in Sweden. 1922. (Engineering, vol. 134, July 7, pp. 5-6.)
Diagrams show construction of the Swedish type of shaft furnace. The economy of electric smelting is discussed.

GOSROW, R. C.
A comparison between shaft and open top furnaces in the manufacture of pig iron electrically from iron ore. 1922. (Am. Electrochem Soc., adv. copy, Apr. 27, 1922, No. 8, pp. 63-74; abst., Jour. Iron and Steel Inst., vol. 105, pp. 552-553.)
Gives reasons for belief that the stacks are not necessary. Gives advantages and disadvantages of plain carbon and graphitized carbon electrodes. The graphitized material allows a better joint, has greater heat conductivity, oxidizes at a higher temperature, and has greater strength for equivalent cross section.

Iron electric smelting. 1922. (Pacific Marine Rev., vol. 19, pp. 126-128.)
The "Elektrometall" furnace consists of the shaft and the hearth. The shaft is provided with a closed furnace top. The electrodes are of circular section and provided with screw joints for joining up end to end. Gas circulation is provided for by a system of fans and nozzles. A sectional elevation of the furnace is given.

SEIGLE, M. J.
Remarques au sujet des changements d'alure dans les hauts-fourneaux électriques. (Remarks on changes in operating electric blast furnaces.) 1922. (Rev. de Mét., vol. 19, pp. 86-89.)

STANSFIELD, ALFRED.
Iron ore smelting by electricity. 1922. (Chem. and Met. Eng., vol. 27, p. 941.)
Outlines the difficulties of electric furnace smelting. It is important to have the right amount of carbon in the charge. Iron is smelted best when the arc is free burning. Electric smelting in Canada must form part of a process in which the ore would be reduced to the metallic state in fuel-fired furnaces at a low temperature before entering the electric melting furnace for the production of steel.

Steel made direct from ore. 1922. (Automot. Ind., vol. 47, p. 216.)

TURNBULL, R.
Synthetic and electric pig iron sanely considered. 1922. (Am. Electrochem Soc., adv. copy, Apr. 27, 1922, No. 18, pp. 259-262; Iron Age, vol. 109, p. 1195.)
Believes that no further advance has been made in producing pig iron from ore in the electric furnace since the experiment conducted at Sault Ste. Marie in 1905-6.

Die Zukunft der electrothermischen Eisengewinnung. (The future of electrothermic iron reduction.) 1922. (Stahl und Eisen, vol. 42, pp. 460-467.)
Criticisms on Helfenstein process known as the "low-charging process."

B. OTHER DIRECT METHODS OF IRON ORE REDUCTION

1911—Furnaces for the direct production of iron or steel from iron ores. 1911. (Mech. Eng., vol. 28, p. 711; abst., Jour. Iron and Steel Inst., vol. 85, p. 536.)
Illustrates two designs of metallurgical furnaces in which flues are formed under the hearth and the hearth is chiefly formed from ground chromite, the object being to construct the hearth of an open hearth furnace fired by gas of such a character as

to resist the action of erosive slags and in such a manner that simultaneously, both from beneath and above, the contents of the hearth may be subjected to high temperatures equal to or exceeding 1600°C. and thus be employed for the direct production of iron and steel from iron ores.

The Jones process for "metallizing" ore. 1911. (Iron Age, vol. 88, p. 1305.)
Describes method to be undertaken at Republic, Mich. The ore is crushed and passed over three-quarter inch mesh. Into the first pair of tubes, 2½ tons of the siliceous ore is charged, mixed with coal. The charge is heated to 1500° and is partially reduced. Reduction takes place further in the second furnace of the pair. Crushing is followed by magnetic separation which removes the silicate from the metal. The crushed metal is then formed into briquettes.

1912—AMSLER, W. O.
Exothermic steel. 1912. (Met. and Chem. Eng., vol. 10, pp. 559-562; disc., pp. 712-713, 774-776.)
Process consists in taking a mixture of iron ore, feldspar, lime, and bauxite, and heating it to about 1000°C. in a graphite crucible. At this temperature a violent reaction is supposed to take place.

EDWARDS, G. E.
The metallization of low-grade iron ores. 1912. (Min. and Eng. World, vol. 36, pp. 553-554.)
Describes the Jones process: a low-grade ore is taken, and by bringing it into contact with volatile matters of coal or wood and the fixed carbon found in coal or wood, the oxygen is driven out of the iron oxide, leaving the iron in a metallic condition without in any way fluxing or melting the iron or gangue; then by a process of magnetic concentration, the iron is freed from its gangue, and as a result a product is obtained possibly of high enough grade to use in an open hearth furnace.

GRÖNDAL, G.
Berättelse öfver vid Herräng gjords försök att reducera järnmalm. (Experiments in the reduction of iron ore at Herräng, Sweden.) 1912. (Jernkontorets Ann., vol. 67, pp. 158-179; abst., Jour. Iron and Steel Inst., vol. 86, pp. 528-529; Iron and Coal Tr. Rev., vol. 65, p. 310.)
Describes large scale experiments in the reduction of iron ore at Herräng in Sweden. The process is as follows: by means of the necessary fuel for reduction purposes the iron is heated in a rotary furnace drum until a suitable temperature is obtained. The circulating gas, produced by the mixture is drawn from the drum and heated in a regenerator, from which it is conducted back into the drum, where it then heats the ore and coal to the temperature necessary for reduction. A gradual reduction of the ore is obtained while it is passing through the rotary furnace. The degrees of oxidation are gradually lowered by means of the increasing heat, and the materials thus converted into iron sponge. The product contains from 97 to 98 per cent. iron and 0.014 to 0.028 per cent. of sulphur. Fuel consumption is low and waste wood or coke from peat can be used without detriment to the quality of the product.

Herstellung von Eisenschwamm nach dem Verfahren von Sieurin in Hogänäs. (Manufacture of iron sponge in Hogänäs.) 1912. (Stahl and Eisen, vol. 32, p. 830; abst., Jour. Iron and Steel Inst., vol. 86, p. 529.)
Spongy iron is now being prepared in relatively large quantities. As raw material, an ore containing 71.3 per cent. iron, 0.001 per cent. sulphur, and 0.009 per cent. phosphorus is used. For reduction a special fuel is used, known as Höganäs coal, and only one quality of iron sponge has been produced which has approximately the following composition: iron, 96 to 97 per cent.; sulphur, 0.01 to 0.02 per cent.; phosphorus, 0.012 per cent.; alumina, 0.6 per cent.; gangue, 23 per cent.

Une nouvelle matière première pour aciérie. (A new raw material for steel works.) 1912. (Rev. de Mét., vol. 9, pp. 304; abst., Jour. Iron and Steel Inst., vol. 85, p. 534.)
Describes a new raw material for steel works, known as Swedish sponge. It is obtained by reducing briquettes of ore by means of carbon monoxide at a temperature below the fusion point of iron. Pure magnetite is employed and the resulting briquette is of a bluish-black colour.

1913—CLARK, W. W., and KEMERY, P.
Exothermic steel. 1913. (Met. and Chem. Eng., vol. 11, pp. 207-209.)
Give reports of experiments made using the exothermic process. Mr. Clark does not consider that the process is a process and says that no exothermic reaction occurs. Mr. Kemery said that in case anything like steel was produced, it contained 0.134 per cent. sulphur.

HANDY, J. O.
Recent progress in applied chemistry and in engineering. 1913. (Proc. Eng. Soc. Western Pennsylvania, vol. 29, pp. 1-62.)
Pp. 29-31: refers to the production of spongy iron in Sweden. This is being commercially produced by the Höganäs-Billesholms Aktiebolag, at Höganäs, Sweden, and the product exported to Germany for use in open hearth steel manufacture. The method of operation is to deposit alternate layers of coal and ore in a refractory vessel, cylindrical in shape, which is sealed against the entrance of air and is placed in a ring kiln of the Hofmann type. The kiln is fired with producer gas made from an inferior coal, and the vessels are successively heated and cooled, the whole process taking from five to seven days. Fuel consumption is very economical.

1914—BARTHEN, I.
Swedish iron and steel developments in 1913. 1914. (Iron Age, vol. 93, pp. 252-254.)
States that 4,000 tons of iron sponge per year is produced at Höganäs, where the only coal in Sweden is used. Mentions the electric smelting furnaces.

HARDER, E. C.
The iron industry in Brazil. 1914. (Bull. Am. Inst. Min. Eng., pp. 2573-2586.)
For smelting the ore by the direct process two types of furnace are used: the closed or crucible furnace and the open or Italian furnace. In the crucible furnaces, which are 4 feet high, 5 feet wide, and 10 feet long, the smelting operations consist in filling the crucible with successive layers of charcoal and pulverized iron ore, slightly dampened, then igniting and applying the blast. More ore and charcoal are added as the charge settles until a bloom of upward of 25 pounds is produced. No fluxing material is used. In the Italian furnace the blast enters through the rear wall.

LYON, D. A.
Some present day metallurgical problems. 1914. (Jour. Franklin Inst., vol. 177, p. 214.)
Analyzes some problems yet to be solved in connection with reduction of iron ores in the electric furnace. Briefly describes some of the earlier methods of direct reduction of iron ores.

1915—Furnaces for making steel from ore. 1915. (Iron Tr. Rev., vol. 57, pp. 743, 764.)
Describes the Otto furnace which has five reducing and melting chambers. The process is said to be distinct from a purely electric process. Diagrams show the construction.

1919—MOFFAT, J. W.
A new method for the smelting of iron ores. 1919. (Can. Min. Jour., vol. 40, pp. 207-210; Can. Machy., vol. 21, pp. 325-327; Can. Foundryman, vol. 10, pp. 119-121.)
The process is a method of duplexing a reducing or metallizing furnace with an electric melting furnace. Iron sponge is first produced and melted in the electric furnace.

Pig iron, ferros and sponge iron at Héroult. 1919. (Chem. and Met. Eng., vol. 20, pp. 613-615.)
Gives a brief history of the plant. Iron sponge has been made recently on a small scale, the estimated cost being $19 a ton.

STANSFIELD, ALFRED.
Electric smelting of iron ores. 1919. (Chem. Eng. and Min. Rev., vol. 11, pp. 224-225; Bull. Can. Min. Inst., July, 1919, pp. 706-709.)
Believes that a method whereby the ore is reduced at a moderate temperature by ordinary fuel heat and later melted in the electric furnace may be more advantageous than the Swedish method. The Moffat process covers this principle as does the method of Trood and Darrah who are working at Héroult, Calif.

STANSFIELD, ALFRED.
Electric smelting of iron ores in British Columbia. 1919. (Iron and Steel Can., vol. 2, pp. 4-10, 34-42, 63-67, 98-111, 132-143; Iron and Coal Tr. Rev., vol. 98, p. 287.)
Reports investigation of processes, especially the Trood and Darrah process, inasmuch as electric power is too expensive for the ordinary electrical methods. Gives information with regard to the supply of iron ores, electrical power, charcoal, labour, etc.

Dr. Stansfield's report on electric smelting of B.C. iron ores. 1919. (Can. Min. Jour., vol. 40, pp. 54-56.)
Refers to a new process by which granulated oxidized ores mixed with carbon are roasted in a fuel-fired furnace and thus reduced to the metallic state. This reduced metallic sand is then melted in an electric furnace at an expenditure of one-third the electric power required both to reduce and melt the ore in the electric furnace. This process is not available at present, but may bring electric smelting within reach in the future.

Tiemann, H. P.
Iron and steel, 1919, New York, McGraw-Hill, pp. 514.
Pp. 134-148: describes briefly a large number of direct processes, including the Adams' American bloomary, A. E. L. Belford's, Berner, Blair, Bull's, Cadinho, Carbon Iron Company's, Catalan, Chenot's, Clay's, Conley, Edward Cooper, Corsican, De Laval, Du Puy, Ehrenwerth's, Eustis, Gerhardt, German bloomary, Graff, G. Gunther's, Gurlt, Harvey, Hawkins, Hofer's, Husgafvel's, Imperatori, Ireland, Irving, Italian, Jones, Knowles, Larkins, Lash-Johnson, Laureau, Leckie, Lebermeister, Lucas, Mattiessen's, Mushet's, Neville, Newton, Nyhammer, Osmund, Otto, Ponsard's, Ramdohr's, Jacob Reese's, Rinton, G. Rogers, Rudolph-Landin, Särnström, Sattman and Homatsch's, Schmidhammer, C. W. Siemans', F. Siemens, Snelus, Stromborg's, Swedish metallic sponge, Toorangin, Trosca, Twynam, Westman's, Wilson's and Yates' processes. Pp. 152-165: describe briefly the various electric furnaces used for iron ore reduction.

Way to make steel direct from ore. 1919. (Iron Tr. Rev., vol. 65, p. 366.)
The apparatus consists of an adaptation of a blast furnace provided with a hearth. The reducing and fusing functions are entirely separated. The furnace was invented by Luis Tegero Grouselle.

1920—Miltoun, F.
Will exploit new steel-making process. 1920. (Iron Tr. Rev., vol. 67, p. 1335.)
Describes briefly the Basset process which uses an inclined rotating furnace. The ore is charged at the upper end and works its way slowly toward the lower end.

Moffat, J. W.
A direct process for making iron and steel from ore. 1920. (Iron and Steel Can., vol. 3, pp. 271-274.)
Describes the Moffat process which consists first in metallizing the ore and later in melting it down.

Steel from iron oxide sand in Japan. 1920. (Engineering, vol. 130, p. 643.)
The Japanese process is guarded as a military secret.

Wust, F.
Betrachtungen über die durekte Eisenerzeugung. (Direct production of iron.) 1920. (Zeit. des Ver. deut. Ing., vol. 64, p. 1011; abst., Jour. Iron and Steel Inst., vol. 103, p. 409.)
Criticizes the Basset process. Basset claims to be able to produce malleable iron 70 per cent. cheaper than by the ordinary method of making wrought iron, the cost of the necessary plant being 80 per cent. less. He attempted to avoid the reoxidation of the reduced iron from carbon dioxide by firing with powdered coal in air at 1000°C. burnt to carbon monoxide only. This proved impracticable, and the temperature necessary to melt wrought iron is not attained. It has been tried to burn the carbon to carbon dioxide and the remainder to carbon monoxide but the oxidizing effect on the reduced iron results in a large proportion of iron passing into the slag. Wüst shows that Basset's calculations concerning the fuel consumption are erroneous.

1921—Bourcoud, A. E.
Direct process for steel manufacture. 1921. (Year Book Am. Iron and Steel Inst., 1921, pp. 355-432; Blast Fur. and Steel Plant, vol. 9, pp. 698-700; Iron Age, vol. 109, pp. 1349-1351.)
Compares the blast furnace and direct processes and analyzes the problems involved in using a direct process.

Cone, E. F.
Steel direct from the ore; recent attempts at producing steel without the intervention of the blast furnace. 1921. (Sci. Am. M., vol. 4, pp. 67-68.)
Gives brief account of Basset, Bourcoud, and Moffat processes.

Cram, P. H.
New method of manufacturing cast iron and steel in France. 1921. (U.S. Dept. Com., Commerce Repts., No. 130, June 6, p. 1330.)
It is stated that Basset Steel Works, after having concluded successful experiments in a 100-ton furnace, will construct 12 Basset furnaces for direct manufacture of steel having a total daily capacity of 3,000 tons.

La fabrication directe du fer et de l'acier à partir du minerai. (Direct process of manufacture of iron and steel from the ore.) 1921. (Metallurgie, vol. 53, pp. 385-386, 435-438, 826-828.)

Gandini, A.
Le moderne vodute sui forni a reduzione per minerali di ferro. (Modern views on furnaces for the reduction of iron ore.) 1921. (Giorn. Chim. Ind., vol. 3, pp. 494-498.)
Discusses Basset process and the Tinfos and Moffat furnaces. Describes a blast furnace invented by the author in which the ore is calcined by means of waste gases from the reduction processes, this stage of the operation being carried out in the upper portion of the furnace. Pulverized fuel is introduced in the middle third of the furnace and the actual reduction takes place in the hearth where the electrodes impinge in the partly reduced ore and coal mixture.

Guedras, M.
La production du fer par reduction directe des minerais par vou électrothermique. (Production of iron by direct electrothermic reduction of the ore.) (Levoz process.) 1921. (Tech. Moderne, vol. 13, pp. 264-265; Chem. and Met. Eng., vol. 26, pp. 34-35.)
First oxides of iron, manganese, and other easily reducible metals are reduced by carbon in a reduction furnace so designed that the aluminum silicates of the ore react with the iron oxides in the presence of C, to give ferrosilicon and alumina, which later dissolves in the cryolite flux which is added to the charge. Second, a complex ferro-alloy is formed which is a powerful reducer. Third, the molten mass flows into an electric furnace containing a charge of the ore to be reduced. The ferro-alloy reacts with the oxides in the ore with the evolution of great heat. The slag containing the silicon, manganese, aluminum, and calcium is easily separated from the pure iron.

Houbaer, E.
Nouveau procédé directe pour la fabrication du fer et de l'acier. (A new direct process for the manufacture of iron and steel.) 1921. (Rev. Univ. des Mines, vol. 11, pp. 45-47.)
Gives a short description of the Bourcoud process.

Lang, H.
Another direct process for steel making. 1921. (Iron Age, vol. 107, pp. 1237-1238.)
The Direct Steel Process Company's method consists in the reduction of the iron ore to iron sponge by the agency of ordinary carbonaceous fuels and the melting of the sponge immediately on its formation, the process being continuous. It differs from previously proposed methods in that the material is not allowed to cool from the beginning to the end of the operation. The process can utilize fine-grained materials. A plant will be built at Santa Cruz on Monterey bay, Calif.

Levoz process for the direct reduction of iron ore in the manufacture of iron and steel. 1921. (Rassegna Min. Met. e Chim., vol. 54, pp. 29-30; abst., Jour. Iron and Steel Inst., vol. 104, p. 368.)
"The process is carried out in three stages in a specially designed electric furnace. The oxides of iron, manganese, and silicon in the charge are reduced in the first stage. In the second stage, some of the Al_2O_3 introduced with the charge, is reduced, giving an iron free from carbon and containing silicon, calcium, and aluminum. In the third stage, the impurities are oxidized to a fusible slag, the heat of the reaction carrying the metal to a very high temperature. Cryolite is added to facilitate the reactions and the separation of the slag."

Making steel direct from ore; Basset's process. 1921. (Iron Tr. Rev., vol. 68, pp. 1375-1376; Foundry, vol. 49, pp. 689-690.)
Compares Basset and Jones processes. The plant of the Direct Steel Process Company, Santa Cruz, Calif., for the utilization of magnetic iron sands, will comprise four reduction furnaces in which the ore is reduced to iron sponge, a melting furnace, and an electric refining furnace. Pulverized ore mixed with fuel and the necessary fluxes are contained in closed receptacles or retorts. These retorts travel through the reducing furnace by gravitation where the ore is reduced to sponge, which is melted, along with the retort, in the melting furnace.

New process of steel manufacture. 1921. (Mech. Eng., vol. 43, p. 36.)
In the Basset process an inclined rotating furnace is employed. The ore is charged at the upper end and works its way toward the lower end as the furnace revolves at the rate of one revolution in three minutes. Pulverized coal is used for fuel.

Le Procédé "Basset." (The "Basset" process.) 1921. (Outillage, vol. 5, Dec. 1, pp. 1259-1260, 1287-1288.)
Explains in detail the technique of the Basset process, quoting the patents protecting it.

Statham, Noel.
The Canadian steel industry and the direct process. 1921. (Iron and Steel Can., vol. 4, pp. 91-98.)

Describes the Bourcoud open-cycle, direct process and gives particulars of costs per ton of steel by this process as compared with the open hearth process.

Sutherland, W. F.
Steel direct from ore by Moffat process. 1921. (Iron Age, vol. 107, pp. 1450-1452.)
A batch of ore is fed into the reducing furnace, held there until reduced, then transferred to the electric furnace in the sponge state, there to be melted down and finished in the bath. The plans of the metallizing furnaces are given.

Wickenden, L.
Smelting ore by direct process. 1921. (Iron Tr. Rev., vol. 69, pp. 363-368.)
Describes Bourcoud spiral furnace and the principles involved in the open-cycle, direct process. A special type of gas producer is used.

Wust, F.
Das Basset-Verfahren zur direkten Eisenerzeugung. (Steel direct from ore by Basset process.) 1921. (Stahl und Eisen, vol. 41, pp. 1841-1848; Iron Age, vol. 109, pp. 989-991.)
A rotary kiln of 40 to 50 metres in length and 2.5 metres in diameter is used. It is widened at the lower end where the fuel is burned. Powdered coal is used for fuel. The air is heated to 1000°C. The ore is finely ground. The inventor claims that the carbon is burned only to carbon monoxide. The claims regarding saving in labour and production costs are not substantiated on examination. Finished steel can be produced only if very pure ore is used.

1922—Illies, H.
Eisenherstellung auf direktem Wege. (Direct production of iron.) 1922. (Feuerungstecknik, vol. 10, pp. 161-164.)
Reviews briefly the Jones, Lang, and Basset processes and describes in some detail the Bourcoud spiral oven process.

La producción directa del acero. (The direct production of steel.) 1922. (Bol. Soc. Fomento Fabril, vol. 39, pp. 151-156.)
Describes the Basset process in detail.

La producción del fierro por reducción directa de minerales via electrotérmica. (Production of iron by the direct electrothermal reduction of ore.) 1922. (Bol. Soc. Fomento Fabril, vol. 39, Jan., pp. 43-46.)
Describes the Levoz process.

Stoughton, Bradley.
Electrolytic iron a commercial product. 1922. (Iron Age, vol. 109, pp. 32-36; Chem. and Met. Eng., vol. 26, pp. 128-131; Chem. Age, vol. 30, pp. 131-133.)
States that the projected application of the Eustis process is made to an iron sulphide ore containing a small amount of copper and the operations will deliver in marketable form, the iron, sulphur, and copper in one short series of processes. The sulphur yielded would cover the cost of the sulphur production and the cost of the ore. Hydrogen is the only serious impurity and it can be removed by baking.

Whitfield, R.
Production of iron and steel direct from the ore. 1922. (Iron and Coal Tr. Rev., vol. 105, p. 84.)
Describes the Basset and Bourcoud processes. The latter depends on the generation of a strongly reducing gas at a high temperature, and the application of the gas so generated, to iron oxide in a rotary furnace without further heating.

2. Beneficiation and Reduction of Magnetic Iron Ores

1881—Clark, E., Jr.
Ore dressing and smelting at Pribram, Bohemia. 1881. (Tran . A.I.M.E., vol. 9, pp. 420-461; abst., Eng. and Min. Jour., vol. 32, p. 237.)
Separation of iron ore from zincblende by magnetic machine.

1883—The Buchanan magnetic separator. 1883. (Eng. and Min. Jour., vol. 35, p. 133.)
Separator used at Block island on magnetic sands.

1884—A test of the Buchanan magnetic separator. 1884. (Eng. and Min. Jour., vol. 38, p. 216.)
Brief note of test made on Beach Glen magnetite carrying 45.71 per cent. metallic iron, yielding concentrates carrying 63.04 per cent. iron.

1887—Linkenbach, C.
Die aufbereitung der Erze, 1887, Berlin. (Abst., Jour. Iron and Steel Inst., 1887, pp. 341-342.)
Pp. 111-117: magnetic separation of magnetite and spathic iron.

Magnetic ore separator. 1887. (Eng. and Min. Jour., vol. 43, p. 152.)
Brief note describing Wenström separator for the concentration of magnetic iron ore.

Ruttmann, F. S.
Concentrating magnetite with the Conkling jig at Lyon Mountain, N.Y. 1887. (Trans. A.I.M.E., vol. 16, pp. 609-623.)
Ore concentrating machine for use with lean ores.

1888—Birkenbine, J., and Edison, T. A.
The concentration of iron ore. 1888. (Trans. A.I.M.E., vol. 17, pp. 728-744.)
Wet and dry concentration, magnetic concentration, including process with Buchanan separator at Croton, N.Y.; Conkling, Monarch, and Edison separators.

Maynard, G. W., and Kunhardt, W. B.
On the dressing of non-Bessemer ores. 1888. (Sch. Mines Quart., vol. 8, pp. 145-162; abst., Eng. and Min. Jour., vol. 45, pp. 232, 252-253.)
Dressing of an Adirondack magnetite.

Ruttmann, F. S.
Concentrating magnetite with the Conkling jig at Lyon Mountain, N.Y. 1888. (Trans. A.I.M.E., vol. 16, pp. 609-623; Eng. and Min. Jour., vol. 45, pp. 416-418.)
Description and illustration of jig.

Venström magnetic separator. 1888. (Eng. and Min. Jour., vol. 46, p. 437.)
Magnetic separator to concentrate magnetic iron ore.

1889—Birkenbine, J.
The Buchanan magnetic rolls. 1889. (Jour. U.S. Assoc. Charcoal Iron Workers, vol. 8, pp. 107-109; abst., Jour. Iron and Steel Inst., 1889, p. 243.)
Magnetic rolls at the Croton mines, N.Y.

The Buchanan magnetic ore separator. 1889. (Eng. and Min. Jour., vol. 47, p. 542.)
Illustrated description of improved separator for treating magnetic iron ore.

Cook, R. A.
The Wenström magnetic separator. 1889. (Trans. A.I.M.E., vol. 17, pp. 599-606; Iron Age, vol. 43, pp. 918-919; abst., Oest. Zeit. f. Berg- u. Hütt., vol. 38, p. 307.)
Description of machine patented by Jonas Wenström of "Orebro," Sweden; data on use at Dannemora.

1890—Ball, C. M.
The Ball Norton electromagnetic separator. 1890. (Trans. A.I.M.E., vol. 19, pp. 187-194; abst., Oest. Zeit. f. Berg- u. Hütt., vol. 39, pp. 450-451.)
Description of machine and use; and analyses from tests.

Birkenbine, J.
Progress in magnetic concentration of iron ore. 1890. (Trans. A.I.M.E., vol. 19, pp. 656-674.)
Review of papers on magnetic concentration at the Tilly Foster, Michigamme, and Benson mines, and discussion of the magnetization of iron ores.

FOWLE, J. C.
Magnetic concentration at the Michigamme iron mines, Lake Superior. 1890. (Trans. A.I.M.E., vol. 19, pp. 62-79; abst., Eng. and Min. Jour., vol. 50, p. 628.)
Use of Wenström and Buchanan separators on crude, 50 per cent. iron ore, giving 65 per cent. concentrates.

Monarch ore separator. 1890. (Eng. and Min. Jour., vol. 50, pp. 269-333.)
Ball-Norton magnetic separator for magnetic ore, results with Clover Hill, Benson Mines, Lyon Mountain, and Port Henry ores.

1891—Ball Nortons elektromegnetiska separator. 1891. (Teknisk Tidskrift, 1891, pp. 193-195.)
Description of separator application to magnetic iron ore, and table of results of magnetic concentration of magnetite.

Ball Norton's magnetischer Erzseparator. 1891. (Oest. Zeit. f. Berg- u. Hütt, vol. 39, p. 345, plate.)
Brief notice of Ball-Norton magnetic ore separator.

HOFFMANN, W. H.
Practical results in the magnetic concentration of iron ore. 1891. (Trans. A.I.M.E., vol. 20, pp. 602-609; Can. Min. Rev., vol. 10, p. 231.)
Apparatus and results obtained by magnetic concentration at Brewster, N.Y.

SAHLIN, A.
Concentration of magnetic iron ore at Weldon, N.Y. 1891. (Eng. and Min. Jour., vol. 52, p. 588.)
Ore reduced by jaw crusher, Krom rolls, Lovett-Finney magnetic separator wheel.

1892—CHASE, H. S.
The Chase magnetic ore separator. 1892. (Trans. A.I.M.E., vol. 21, pp. 503-512.)
Description of apparatus by inventor.

Discussion on the crushing of iron ore for magnetic separation. 1892. (Trans. A.I.M.E., vol. 21, pp. 533-535.)
Includes discussion on papers of W. H. Hoffmann, Trans., vol. 20, pp. 602-609; Trans., vol. 21, pp. 126, 516-530.

Ist die Anreicherung armer Eisenerze auf magnetischen Wege gewin bringend? (Is the enriching of poor iron ores magnetically, profitable?) 1892. (Oest. Zeit. f. Berg- u. Hütt., vol. 40, pp. 425-427, abstracted from Trans. A.I.M.E., 1890-1.)
Refers to magnetic separation of magnetite in New York, New Jersey, and Michigan; considers analytical results of processes.

McDOWELL, F. H.
Magnetic concentration at Tilly Foster. 1892. (Trans. A.I.M.E., vol. 21, pp. 519-521.)
Brief outline of process applied.

NORDENSTRÖM, G.
Om sofring af jarnmaln medelst magnetiska malmskiljare. (The sorting of iron ore by means of magnetic ore separators.) 1892. (Jernkontorets Ann., vol. 47, pp. 99-113.)
Wenström's separator, 1884. Separation at the great Slotterberg mine, at Tuna Hästberg mine, Dannemora, and at the Matts mine.

SAHLIN, A.
Introduction and development of magnetic separation of iron ore. 1892. (Eng. and Min. Jour., vol. 53, pp. 616-617, 638-640, 662-664.)
Pp. 616-617: importance and use of magnetite concentration; p. 638: preparation of the ore, drying, and crushing; p. 662: methods of separation, including Conkling, Buchanan, Edison, Wenström, Ball, and Hoffmann; Lovett-Finney and Chase separators.

SJÖGREN, A.
Om magnetisk anrikning af järnmalmer. (On the magnetic separation of iron ore.) 1892. (Jernkontorets Ann., vol. 47, pp. 49-77.)
Quotes from Birkenbine (Trans. A.I.M.E., vol. 17, p. 739) concerning use of the Conkling separator at the Tilly Foster mine, and (Trans. A.I.M.E., vol. 19, p. 656) discusses costs, application of American methods to Swedish ore. Use of Wenström's separator.

1893—COMMANS, R. E.
The concentration and sizing of crushed minerals. 1893. (Proc. Inst. Civ. Eng., vol. 116, pp. 3-67.)
Pp. 63-66: magnetic separation in iron ore treatment.

The Hibernia concentration plant. 1893. (Iron Age, vol. 52, pp. 202-204.)
Description of magnetic concentrating plant using 24 to 40 per cent. metallic iron ore at Hibernia, N.J. Buchanan magnetic rolls.

LAWRENCE, H. L.
Dressing of zinc blende ores, and magnetite at the new Pierrefitte mines, Hautes Pyrenees, France. 1893. (Trans. Inst. Min. and Met., vol. 2, pp. 92-100; disc., pp. 100-109.)
Considers the processes used to separate the zincblende and pyrites by means of a magnetic separator, comparing the two methods, dressing before magnetic treatment, and magnetic treatment before dressing.

SAHLIN, A.
Användning och framställning of anrikad magnetisk järnmalm i Forenta Staterna. (Application and progress of process for enriching magnetic iron ore in the United States.) 1893. (Jernkontorets Ann., vol. 48, pp. 105-135, 3 inserts.)
Considers the east, Ohio valley, Lake Superior, and southern magnetic iron ore districts. Preparation of magnetic iron ore for enriching by rolling, drying, crushing; methods of separation including Buchanan, Edison, Conkling, Ball-Norton, Hoffmann, Lovett-Finney, and Chase.

SATELIN, J. DE
Preparation mécanique des minerais Trieuse magnétique oscillante (système Hugues Dariot). 1893. (Compt. Rend. Soc. Ind. Min., May, 1893, pp. 52-59.)
Theory, design, and construction of Hugues Dariot magnetic separator for minerals.

Schwedische Resultate der magnetischen Eisenerzscheidung. 1893. (Oest. Zeit. f. Berg- u. Hütt., vol. 40, pp. 485-486.)
Swedish results of magnetic ore separation at Slotterberg, Hästberg, Dannemore, and Mattsgrube.

STEFAN, H.
Magnetische Scheidung von Eisenerzen in Nordamerika. 1893. (Oest. Zeit. f. Berg- u. Hütt., vol. 41, pp. 377-380.)
Magnetic separation of iron ore in North America, including Tilly Foster and Croton mines. Description of separators and process.

1894—WALT, V. VON.
Neuerungen im Aufbereitungswesen. 1894. (Oest. Zeit. f. Berg- u. Hütt., vol. 42, pp. 229-232, 244-246.)
P. 232: Magnetic separator of Hardy Patent Pick Co.; p. 244: Dariot separator, Ball-Norton Monarch.

1895—BALL, C. M.
The magnetic separation of iron ore. 1895. (Trans. A.I.M.E., vol. 25, pp. 533-551.)
Theory, calculations, analysis of products, Ball-Norton separator, work on magnetite in U.S.

CHASE, H. S.
Southern magnetite and magnetic separation. 1895. (Trans. A.I.M.E., vol. 25, pp. 551-557.)
Experience at Cranberry mines, Mitchell county, N.C.

Nya magnetiska anriknings maskiner af svensk fillverkning. (New magnetic ore separators of Swedish manufacture.) 1895. (Teknisk Tidskrift, 1895 A., pp. 238-239.)
Monarch and Ball Norton types in use at Herräng; results of concentration of magnetite.

PHILLIPS, W. B.
Notes on magnetite. 1895. (Eng. and Min. Jour., vol. 60, pp. 149-150, 176, 196-197.)
Occurrence of magnetite, analyses of magnetites, magnetization and concentration of iron ores.

PHILLIPS, W. B.
Notes on the magnetization and concentration of iron ore. 1895. (Trans. A.I.M.E., vol. 25, pp. 399-423; abst., Chem. Zeit., 1896, rept. 30; Oest. Zeit. f. Berg- u. Hütt, vol. 46, p. 657.)
Deals with results in converting a non-magnetic ore into a magnetic ore, then concentrating it over a magnetic separator of the alternate polarity type.

SMITH, E. M.
On the treatment of New Zealand magnetic iron sands. 1895. (Jour. Iron and Steel Inst., pt. I, pp. 65-69; Eng. and Min. Jour., vol. 61, p. 566; Min. Jour., vol. 66, p. 600.)

Formed iron sand with certain clays into a brick, smelted in a blast furnace, obtained soft, grey pig iron.

1896—PHILLIPS, W. B.
Concentration of low-grade Trow ores. 1896. (Eng. and Min. Jour., vol. 62, pp. 75-76, 105-106, 124-125, 151.)
Value of magnetic separation, removal of silica, Wetherill process; application, results of use, analyses.

1897—BECKERT, T.
Die Aufbereitung phosphorreicher Magnetite in Luleä. 1897. (Zeit. des Ver. deut. Ing., vol. 41, pp. 1307-1308.)
The enriching of magnetite rich in phosphorus in Lul:ä, Sweden.

The Edison concentrating works. 1897. (Iron Age, vol. 60, Oct. 28, pp. 1-8, insert.)
Description of low-grade magnetic ore, mining, crushing, rolls, screens, magnetic separators, elimination of phosphorus, flow sheet, lubrication, briquetting plant.

Elektromagnetische Aufbereitung der Eisenerze. 1897. (Stahl und Eisen, vol. 17, pp. 209-214.)
Discusses the products of electromagnetic separation of magnetic iron ore and the principles upon which magnetic separators are constructed, using the Wetherill as illustration.

SVENSON, W.
Magnetisk anrikning of Järnmalm. 1897. (Teknisk Tidskrift, 1897, Kemi, pp. 42-47.)
Magnetic concentration of iron ore. Monarch separators, results and analyses of ores and concentrations.

Trieurs électro-magnétiques Wetherill et leur emploi aux mines de New Jersey (Etats Unis). 1897. (Génie Civil, vol. 31, pp. 54-55.)
Electromagnetic s paration of magnetite by the Wetherill system in New Jersey.

1898—GRÖNDAL, G.
Magnetisk anrikning of jernmalem efter Gröndal Dellvikska metoden. 1898. (Blad för Bergshandter:ngens Vänner inom Obrebro lan, vol. 8, pp. 208-217.)
Magnetic separation of iron ore by the Gröndal-Delvik system.

A Russian magnetic separator. 1898. (Wermsandska Ann.; Eng. and Min. Jour., vol. 66, p. 244.)
Gröndal-Delvik separator for enriching fine iron ore slime 25 per cent. Fe to 66-68 per cent. briquettes at Pitkäranta, Finland.

SCHIFF, F.
Triage magnétique des minerais. 1898. (Génie Civil, vol. 34, pp. 167-170, plate opp. p. 160.)
Magnetic separation of ores, especially magnetite and zinc types of separators.

WEDDING, H.
Die magnetische Aufbereitung von Erzen. 1898. (Verhandlungen der Vereinzur Beförderung des Gewerbefleisses Maiheft, pp. 263-286; abst., Berg- u. Hütt. Zeit., vol. 57, p. 249.)
Includes apparatus for treating magnetic ores, patents, etc.

1899—LEO, MAX.
Magnetische Anreicherung von Eisenerzen nach dem Verfahren von Gröndal Dellwik. 1899. (Stahl und Eisen, vol. 19, pp. 271-273.)
Magnetic concentration of iron ores by the Gröndal-Delvik process as used on magnetite at Pitkäranta, Finland. Forty per cent. ore with 70 per cent. iron content in concentrates.

MCNEILL, H. C.
Some forms of magnetic separators and their application to different ores. 1899. (Jour. Iron and Steel Inst., pt. 2, pp. 18-44, disc. p. 45-52; Eng. and Min. Jour., vol. 68, pp. 608-609, 640-641.)
Describes Wenström, Monarch, Gröndal-Delvik, Heberle, and Wetherill machines, and processes for treating magnetic iron.

PRIMOSIGH, E.
Magnetische Anreicherung von Eisenerzen nach der Methode Grondal Dellwik. 1899. (Oest. Zeit. f. Berg- u. Hütt., vol. 47, pp. 51-53.)
Magnetic separation of iron ores by the Gröndal-Delvik method as followed in Pitkäranta.

1900—LANGUTH, E.
Das elektromagnetische Aufbereitungsprinzip. 1900. (Zeit. f. Elektrochemie, vol. 6, pp. 500-506.)
The electromagnetic separation principle. The theory as applied to the separation of ores.

PETERSSON, W.
Det magnetiska anriknings verket vid Härrang. 1900. (Teknisk Tidskrift, 1900, Kemi, pp. 59-60, 2 inserts.)
Magnetic concentration plants at Herräng using Monarch separator.

SMITS, H.
Magnetische Aufbereitung der Eisenerze. 1900. (Stahl und Eisen, vol. 20, pp. 1186-1193; Bull. Soc. Ind. Min., vol. 14; Eng. and Min. Jour., vol. 71, pp. 399-400.)
Magnetic separation of iron ores, theory, Wetherill process as used by New Jersey Zinc Company, at Franklin, N.Y., and process followed at Lohmannsfeld, Germany.

1901—CRANE, W. R.
Investigations of magnetic fields with reference to ore concentration. 1901. (Trans. A.I.M.E., vol. 31, pp. 405-406.)
Pole distance and pole form; includes apparatus, methods of testing, magnetic permeability, theory and relative magnetic permeability of various ores.

GRÖNDAL, G.
Die magnetische Erzaufbereitung zu Pitkäranta in Finland. 1901. (Glückauf, vol. 37, pp. 565-569, 429-441; Teknisk Tidskrift, 1901, pp. 53-57.)
Magnetic ore separation at Pitkäranta in Finland. Use of separators on magnetite.

OBALSKI, J.
Notes on the magnetic iron sand of the north shore of the St. Lawrence. 1901. (Jour. Can. Min. Inst., vol. 4, pp. 91-98; Can. Min. Rev., vol. 20, pp. 34-37.)
Mentions concentration of the ore in 1868 by Dr. H. Larue's process, consisting in magnets under which an endless table passed with the sand on it.

Wetherills magnetiska separations method. 1901. (Teknisk Tidskrift, 1901, Kemi, pp. 12-15.)
Wetherill's magnetic separation method.

1902—Electric concentration and electric furnace. 1902. (Iron Age, vol. 70, No. 20, pp. 20-21.)
Description of apparatus with which the Salisbury Iron and Steel Company expect to treat rich magnetic ore of 62 per cent. metallic iron with magnetic separation and electric smelting by the Ruthenberg process.

ERIKSSON, K.
Anrikning of malmer. 1902. (Jernkontorets Ann., vol. 57, pp. 1-78, 1 insert.)
Ore concentration. Concentration magnetically, including equipment and process at Friedrichsegen, Laurenburg, Hamberg, Honigsmund, Schöneberg, Bensberg, Böhmen, Caecilia, Kremnitz.

Frodings magnetiska malmskiljare. 1902. (Teknisk Tidskrift, 1902, Kemi, pp. 6-7; Glückauf, vol. 38, pp. 330-331; abst., Oest Zeit. f. Berg- u. Hütt., vol. 50, pp. 241-242.)
Frodings magnetic ore separator in use at Herräng; 25 per cent. ore giving 62 to 64 per cent. concentrates.

Magneteisenerz-Briketts, 1902. (Sachs Jahrb., 1902, p. 174; abst., Oest. Zeit. f. Berg- u. Hütt., vol. 51, p. 236.)
Magnetic iron ore briquettes at St. Christoph, Saxony. Process of manufacture.

SCHNELLE, F. O.
Die neuesten Fortschritte auf dem Gebiete der magnetischen Aufbereitung. 1902. (Stahl und Eisen, vol. 22, pp. 1308-1309, read before the Verein zur Beforderung des Gewerbfleisses.)
Latest progress in the field of magnetic separation. Humbolt type separator for use with zinc or hematite ores.

STUTCHBURY, M.S.
The Pierrefitte concentrating mill. 1902. (Trans. Inst. Min. and Met., vol. 10, pp. 457-461, 3 inserts.)
Magnetite, galena, and blende, using magnetic separator.

WILKENS, H. A. J.
Recent progress in the Wetherill system of magnetic separation. 1902. (Min. Ind., vol. 10, pp. 775-783.)
Design of machines, application; results obtained from use of Wetherill separators.

1903—Fran Vermländska Bergsmanna föreningens Arsmöte i Kristinehamn den 16 April, 1903. (Teknisk Tidskrift, vol. 33, pp. 193-196, 205-207, 213-218.)
From the Bernland Mining Engineers' annual meeting at Christiania, April 16, 1903, pp. 193-194.
Report of committee on concentration of iron ore, dealing especially with magnetic concentration.

The magnetic concentration of iron ore in New Jersey. 1903. (Iron Age, vol. 72, Oct. 22, pp. 16-17.)
Plant for magnetic concentration of magnetite at Phillipsburg using a Ball magnetic separator. Flow sheet, analyses, etc.

The Mineville magnetite mines. 1903. (Iron Age, vol. 72, Dec. 17, pp. 10-19.)
Description and history of mines; p. 15: magnetic concentration and purification, including Wenström, Ball-Norton, Rowand, and Wetherill types of separators.

PETERSSON, W.
Om anrikning of Svenska järnmalmer. 1903. (Jernkontorets Ann., vol. 58, pp. 251-362; abst., Oest. Zeit. f. Berg- u. Hütt., vol. 52, pp. 165-169, 179-181; Teknisk Tidskrift, vol. 34, Kemi, pp. 9-16; 7 inserts.)
Concentration of Swedish iron ore. Describes and gives results and analyses from use of Monarch, Gröndal, Herble, Fröding, Eriksson, Forsgren, Wetherill separators and plants at Herrang, Bagga, Strässa, Lerberg, Persberg, Romme, Bredsjö, Blotberget.

WELLS, J. W.
Magnetic concentration of iron ores. 1903. (Ont. Bur. Mines Rept., vol. 12, pp. 332-337, bibliog., pp. 337-342, 6 plates.)
Status of magnetic concentration types of separators, practice in Europe, experimenting with magnetites from Mayo.

WELLS, J. W.
Progress in magnetic concentration of iron ore. 1903. (Jour. Can. Min. Inst., vol. 6, pp. 6-20, plates; Can. Min. Rev., vol. 22, pp. 134-138.)
Reason for and methods of concentrating iron ores, separators in use, with processes and results.

ZSIGMONDY, A.
Uber den Swedischen Eisenerzbergbau. 1903. (Oest. Zeit. f. Berg- u. Hütt., vol. 51, pp. 279-285, inserts opp. pp. 290, 293, 294; pp. 300-303 translated; insert opp. p. 300 from Bany. es Koh-lapok.)
Swedish iron ore mining. Discussion of Swedish ore production, with more detailed account of ore, and milling processes including magnetic separation at Dannemore, Grangesberg, and Persberg.

1904—CRANE, W. R.
Electro-magnetic separators. 1904. (Mines and Minerals, vol. 25, pp. 224-226.)
Secondary induction type, description of the Knowles magnetic separator.

Electromagnetic concentration of slightly magnetic ores. 1904. (Min. Jour., vol. 75, p. 344.)
Wetherill machine.

HECKER.
Zwei neue magnetische Erzcheider. 1904. (Glückauf, vol. 40, pp. 77-81.)
Two new magnetic separators of the Swedish Concentrating Company (Svenska Anriknings-Aktie at Grängesberg, using new principles, after the system of E. Forsgren and K. Eriksson. Results of use on magnetite and hematite ore.

LEO, MAX.
Neues Separatorsystem zur Anreicherung von magneteisenerzen des Ingenieurs Emil Forsgren, Falun, Sweden. 1904. (Oest. Zeit. f. Berg- u. Hütt., vol. 52, pp. 139-142.)
New types of separators for concentrating magnetic iron ores of Emil Forsgren, Falun, Sweden. Primary and secondary pole types.

Magnetic separation of iron and zinc ores. 1904. (Mines and Minerals ,vol. 25, p. 226.)
Application of process mentioning machines built by the Magnetic Separator Company, and the Wetherill Company.

The Odling magnetic separator. 1904. (Aust. Min. Stand., vol. 27; Eng. and Min. Jour., vol. 78, p. 904.)
Uses unsized material and wet pulp. Results with magnetite.

Ostwald, H.
La preparation magnétique des minerais. 1904. (Rev. Univ. des Mines, vol. 4-6, pp. 194-203; Min. Jour., vol. 75, pp. 468-475.)
The Wetherill system of magnetic separation of iron ores.

Separation of limonite iron ore from zinc silicate. 1904. (West. Min. World, vol. 21, p. 611.)
Note of the commercial application of magnetic separation of limonite iron ore from zinc silicate by the Wyeth Lead and Zinc Company, Austinville, Va., in 1892, and by the Bertha Mineral Company at Delton, Va., in 1901.

Simpkin, W. and Ballantine, J. B.
The Edison process at the Dunderland mines. 1904. (Inst. Min. and Met., vol. 14, pp. 62-73; Iron and Coal Tr. Rev., vol. 69, pp. 1265-1266.)
Includes use of Edison magnetic separator for very low grade ores.

Snyder, F. T.
Magnetic separation. 1904. (Jour. Can. Min. Inst., vol. 7, pp. 270-283; Can. Min. Rev., vol. 23, pp. 86-89.)
Application to magnetite, zinc lead iron separation, manganese, corundum, and magnetite, and particularly to the St. Lawrence magnetic sands.

Uber das Eisenerzbrikett und seine Verhüttung. 1904. (Oest. Zeit. f. Berg- u. Hütt., vol. 52, pp. 589-593.)
Iron ore briquettes and their smelting. Briquettes made at Herräng and Bredsjo by the Gröndal process. Manufacture, analyses, magnetic separation of the ore, power requirements, temperature requirements, etc.

Weiskoft, A.
Brikettering of Järnmalmer. 1904. (Teknisk Tidskrift, vol. 34, Kemi, pp. 1-4.)
Briquetting of iron ore with or without use of binder. Edison's method. Gröndal-Delvik method.

1905—The Ball and Norton belt type magnetic separator. 1905. (Iron Age, vol. 76, pp. 1367-1368.)
Separator used at plant of Witherbee, Sherman and Company, Mineville, N.Y., to separate magnetite from apatite and siliceous gangue.

The Buchanan magnetic separator. 1905. (Iron Age, vol. 75, pp. 1974-1975.)
Description of new drum type of magnetic separator for the treatment of lean iron ores, built by G. V. Cresson Company, Philadelphia.

Esser, F.
Electromagnetische Aufbereitungen nach dem Verfahren von Wetherill. 1905. (Zeit. des Ver. deut. Ing., vol. 49, pp. 704-707.)
Electromagnetic separation by the Wetherill process, of magnetic iron ores. Hill.

The Imperial magnetic ore separator. 1905. (Min. World, vol. 23, pp. 98-99.)
Separator through which the ore passing once is separated into three distinct parts: highly magnetic, feebly magnetic, and non-magnetic.

Magnetic separation. 1905. (Min. World, vol. 23, p. 177.)
Wetherill separator as used for iron or zinc ore concentration.

Robertson, J. F.
Notes on some recent experiments on the magnetic concentration of iron sands from the lower St. Lawrence. 1905. (Trans. Can. Civ. Eng., vol. 19, pp. 287-295.)
Special apparatus and results.

Simmersbach, O.
Magnetische Aufbereitung phosphorreicher Eisenerze in den Vereinigten Staaten von Amerika. 1905. (Stahl und Eisen, vol. 25, pp. 1296-1300.)
Magnetic preparation of phosphorus-bearing iron ore in the U.S. magnetic iron ore at Mineville, N.Y.; separators used, etc.

Snyder, F. T.
The Snyder magnetic separator. 1905. (Eng. and Min. Jour., vol. 80, pp. 396-397.)
Description of machine with analyses of results obtained.

Weiskopf, A.
Uber Anreicherung von Eisenerzen. 1905. (Stahl und Eisen, vol. 25, pp. 471-475, 532-535.)

The concentration of iron ores. Includes design and application of Monarch, Gröndal, Heberless, Fröding, Eriksson, Forsgren separators; table showing results of various separators used in Sweden, giving type of ore, analyses of crude ore, tailings, concentrates, power consumption, etc.

1906—The Ball and Norton magnetic separator. 1906. (Eng. and Min. Jour., vol. 81, p. 75; Iron Age, Nov. 23, 1905.)
Machine used by Witherbee, Sherman and Company for separation of strongly magnetic substances.

BLÖMEKE, C.
Uber das trockene und nasse elektromagnetische Aufbereitungs-verfahren der Hernadthaler Ungarische Eisenindustrie Aktien-Ges. 1906. (Metallurgie, vol. 3, pp. 721-725.)
The wet and dry electromagnetic concentration process of the Hernadthaler Hungarian Iron Industry Company at Budapest; ore, 27 per cent. Fe, gives concentrates 50 per cent. Fe.

BUGGE, C.
Magnetisk malmseparation. 1906. (Teknisk Ugeblad, vol. 24, pp. 209-212, 217-218, 234-237; abst., Oest. Zeit. f. Berg- u. Hütt., vol. 54, pp. 102-103.)
Detailed illustrated description of magnetic ore separation and of Gröndal, Eriksson, Forsgren, Monarch, Buchanan, and Wetherill separators; flow sheet, analyses, etc., from Herräng.

The Ding magnetic separator. 1906. (Eng. and Min. Jour., vol. 81, p. 749.)
Illustrated description of low intensity machine of the induction type.

The Ferraris magnetic separator. 1906. (Eng. and Min. Jour., vol. 82, p. 1129.)
Machine in use on zinc and iron separation at Monteponia, Sardinia, Italy.

GRANBERRY, J. H.
Magnetite deposits and mining at Mineville, N.Y. 1906. (Eng. and Min. Jour., vol. 81, pp. 890-893, 986-988, 1035-1038, 1082-1085, 1130-1132, 1178.)
P. 890: geology; p. 986: ore body; p. 1035: mine working; p. 1082: magnetic separation; p. 1130: power stations; p. 1178: by-products, machine shops.

Hidburg magnetic separator. 1906. (Eng. and Min. Jour., vol. 81, p. 418.)
Brief mention of Hidburg separator, U.S. Pat. 805, 854, especially designed for handling hot ore (about 250°F.)

KORA, D.
La separation électromagnétique et électrostatique des minerais, 1906, Paris, L'-Eclairage Electrique.
Describes separation of magnetic iron ore in United States and Sweden.

NEWLAND, D. H., and HANSELL, N. V.
Magnetite mines at Lyon Mountain, N.Y. 1906. (Eng. and Min. Jour., vol. 82, pp. 863-865, 916-918.)
P. 917: magnetic separation with Ball-Norton double drum separator.

TABRE, L.
Les separateurs magnétiques. 1906. (L'Electricien, vol. 31, pp. 100-103, 121.)
Wetherill type machine constructed by Humboldt at Kalke near Cologne; metallurgische Gesellschalft machine, for use in treatment of magnetic iron ores.

1907—BENNIE, P. McN.
Magnetic concentration of iron ores by the Gröndal process. 1907. (Jour. Can. Min. Inst., vol. 10, pp. 261-273; Can. Min. Jour., vol. 28, pp. 202-206; Min. World, vol. 26, p. 360; Min. Rep., vol. 55, p. 473; Rev. de Mét., vol. 4, p. 437; Electrochem. and Met. Ind., vol. 5, p. 134.)
Development of process, results of treatment at Herräng, Gellivare, Sweden; Salangem, Norway; Pitkäranta, Finland; Cornwall, Pa.

CIRKEL, FRITZ.
The treatment of magnetic iron ore. 1907. (Jour. Can. Min. Inst., vol. 10, pp. 108-117; abst., Min. World, vol. 27, pp. 59-60.)
Outlines process as followed by Witherbee, Sherman and Company, at Mineville, N.Y.

Concentrating magnetite ore. 1907. (Min. World, vol. 27, p. 639.)
Outline of process used by the Delaware and Hudson Company at Lyon Mountain, N.Y., where magnetite, 32 per cent. iron, is treated.

Petersson, G. W.
Magnetic separation of iron ore in Sweden. 1907. (Eng. and Min. Jour., vol. 83, pp. 889-896; Rev. de Mét., vol. 4, p. 600.)
Twenty-one plants, type of separator given in operation, producing 63 to 65 per cent. iron concentrates from ore carrying 25 to 30 per cent., flow sheets, separators, etc.

Utilizing impure iron ores. 1907. (Min. World, vol. 26, pp. 360-361.)
Gröndal magnetic separating and briquetting process for low-grade magnetite ore.

1908—Bartsch, J. W.
Le traitement magnétique des minerais et son emploi, dans le pays de la Siegerland pour minerais de fer spathiques. 1908. (Rev. Univ. des Mines, vol. 23, pp. 93-130.)
Magnetic treatment of ores and its use in the valley of the Siegerland, Germany, for spathic iron ores theory; installation at Bruderbund, Klautage; Wetherill separators.

Bennie, P. McN.
Progress with the Gröndal process of concentrating and briquetting iron ores. 1908. (Jour. Can. Min. Inst., vol. 11, p. 189; Can. Min. Jour., vol. 29, pp. 332-335.)
List of works where Gröndal process is in use, development at Sydvaranger, changes in process, fuel economy, market process, and application of process to magnetite mines of Central Ontario.

Franke, G.
Mitteilungen über einige neurere schwedische Anlagen und Verfahren für Aufbereitung und Brikettierung von Eisenerzen und Kiesabbränden. 1908. (Glückauf, vol. 44, pp. 1417-1427, 1453-1460, 1 inserted plate.)
Notes on a new Swedish plant and process for the concentrating and briquetting of iron ores and pyrites. Magnetic iron ores reduction and briquetting at Flogberget, Sweden, using Gröndal separators. Flow sheet, etc. Briquetting at Helsingborgs Copper Works. Magnetic separation of Ekman and Markman at Vinjern.

The Gröndal process of magnetic concentration and briquetting. 1908. (Min. Jour., vol. 83, p. 250; Revista Minera, vol. 59, p. 91.)
Table of the results obtained in magnetic concentration and compression of ore by the Gröndal process at some of the Norwegian and Swedish works.

Hansell, N. V.
Jarmalmsanrikning medsärskildta afseende pa amerikansk praktik. 1908. (Jernkontorets Ann. Beihang, vol. 9, pp. 1-11, 1 insert.)
Iron ore enriching with especial reference to American practice at Lyon Mountain, Port Henry, Hibernia, N.J.; Lebanon, Pa. Apparatus, including crushing machines, sifters, magnetic separators, kilns, power machinery.

Horel, U.
Die magnetische Aufbereitung und ihre Anwendung für gerös tenten Spateisenstein im Siegerlande. 1908. (Oest. Zeit. f. Berg-u. Hütt., vol. 56, pp. 317-323.)
Magnetic separation and its application to roasted siderite in Siegerland, separators used, flow sheet.

McKenzie, G. C.
The iron and steel industry of Canada. 1908. (Ont. Bur. Mines, vol. 17, pp. 190-342; abst., Min. World, vol. 30, pp. 887-889.)
P. 226-278: Magnetic concentration of iron ores, process of concentration of magnetite, types of magnetic separators, including Conkling, Wetherill, Ball-Norton, Gröndal, with detailed account of Gröndal process. Magnetic concentration at Mineville, N.Y.; at Cedar Point furnace, Port Henry, N.Y.; Lyon Mountain, N.Y.; Standish furnace, N.Y.; Lebanon, Pa. Concentration tests with Ontario magnetites, cost of Gröndal plant, cost of dry magnetic concentrating plant.

1909—Dreves, E.
Grundsätze für den Betrieb mit Magnet-Separatoren bei der magnetischen Erzaufbereitung. 1909. (Zeit. des Oberschlesischen Berg- und Hütt. Ver., vol. 48, pp. 525-531, plate opp. p. 570.)
Principles of the operation of magnetic separators for the enriching of magnetic ores, treats subject mathematically, curves of iron content of ore and concentrates.

Ekman, G.
Anreicherung und Röstung von Magneteisenstein nach einem für Schweden neuen Vergahren. 1909. (Blad für Bergshandteringens Vanner, 1909, pp. 340-354; abst., Stahl und Eisen, vol. 29, p. 979.)
Concentrating and roasting magnetite ore by a new method in Sweden.

GUNTHER, C. G.
Electro-magnetic ore separation, 1909, New York, Hill Publishing Co., pp. 193.
Pp. 3-8: magnetism applied to ore dressing; pp. 9-21: principles of magnetic separation and preparation of ore for treatment; pp. 22-60: separators for strongly magnetic minerals; pp. 61-78: separators for feebly magnetic minerals; pp. 79-114: concentration of magnetite ores; pp. 115-137: separation of pyrite from blend; pp. 138-153: separation of siderite from blende.

LOUIS, H.
The dressing of minerals, 1909, New York, Longmans, Green & Co., pp. 544.
Pp. 385-440: magnetic separation; minerals that can be milled magnetically; separators; employing moving magnets, wet working magnetic concentrators. Many illustrations.

RICHARDS, R. H.
Ore dressing, 1909, New York, McGraw-Hill Book Co., vol. 1, p. 702.
Pp. 393-413: magnetic separation and concentration; when applicable; electromagnets; classification of magnetic separators, primary magnetic type, including cobbing magnets, belt-type, drum type; induction magnet type including belt-type, drum type; roasting or calcining for magnetism.

RICHARDS, R. H.
Ore dressing, 1909, New York, McGraw-Hill Book Co., 4 vols.
Vol. 3, pp. 1521-1543: magnetic concentration, separators of the primary-magnet type, of the induced magnet type.

1910—Experimental magnetic concentration plant in Canada. 1910. (Eng. and Min. Jour., vol. 90, p. 908.)
Notice of installation of Gröndal ore separation plant for the testing of low-grade magnetic iron ores by Mines Branch of the Canada Department of Mines.

HANSELL, N. V.
The concentration of magnetic iron ores. 1910. (Eng. Mag., vol. 38, pp. 513-536.)
Principles of magnetic concentration, magnetic separation, cobbing machine dry separators, and wet separators for the enrichment of magnetite concentrates; Mount Hope cobbing plant, Mineville separating plant, Lyon Mountain and Lebanon concentrating plants.

MCKENZIE, G. C.
Concentration of low grade magnetites. 1910. (Ont. Bur. Mines, vol. 19, pp. 154-172, 5 inserts; abst., Eng. and Min. Jour., vol. 90, p. 1312; Jour. Can. Min. Inst., vol. 12, p. 130; Min. World, vol. 32, p. 63; Min. Sci., vol. 61, p. 81.)
Economical concentration, relative value of ores at the furnaces, ores tested, machines used, crushing, grinding, concentrating, tabulation, details of each test, conclusions, and costs.

MCKENZIE, G. C.
Magnetic concentration of Bristol ores. 1910. (Can. Dept. Mines, Mines Branch, Bull. 2, pp. 12-15, 2 inserts.)
Results of separation processes in the Gröndal wet process separator and Ball-Norton belt separator, of magnetite from Bristol mine, Pontiac, Que.

Om anrikning av jermalm, saerlig ved smaa Forekoster or ved Forsoksarbeider. 1910. (Teknisk Ugeblad, vol. 28, p. 653.)
Enriching of iron ore, especially that of poor quality or for experiments.

PETERSSON, W.
Den svenska järmalmsanrikningens newarande standpunkt. 1910. (Jernkontorets Ann., vol. 65, pp. 254-344; disc., pp. 385-399.)
Swedish iron ore concentration from the present view point. Pp. 261-335: magnetic separation at Herräng, Bredsjö, Högberget, Romme, Klacka, Lerberg, Björnberget, Blötberget, Kallmora, Länggrufvan, Uttersberg, Flogerget, Vintjärn, Södra Hyttan, Karlsvik, Sikfors, Slotterberg, Riddarhyttan, Vegelsbo, Persberg, Timansberg, Långbanshyttan, Baggä, Strässa, Lomberget Västra Ormberget, Guldsmedshyttan, Kantorp, Dalkarlsberg, Svartön, Dannemora, Skottgrufvan, Grängesberg. Apparatus, flow sheets, etc.

The South Varanger iron ore deposits and separating and briquetting plant. 1910. (Engineering, vol. 90, pp. 383-386.)
Magnetite ore separated with Gröndal separators. Details of power equipment.

Uhrn, E.
Kortfattad jamforelse melan svenska och amerikanska metoder för magnetisk anrikning samt brikett ring af järmalmer enligt intryck from an resai Nord-Amerika, 1909. 1910. (Jernkontorets Ann. Beihang, vol. 11, pp. 736-745.)
Short review of Swedish and American methods of magnetic enriching and briquetting of iron ore, including comparison of costs of installation and production, by the Gröndal and belt-type separators.

1911—Cameron, J. M.
The Cranberry iron ore mine. 1911. (Mines and Minerals, vol. 32, pp. 42-44.)
Includes description of electromagnetic concentrating of high-grade magnetite at Mitchell county, N.C.

Comstock, H.
A large modern iron ore concentrating plant. 1911. (Iron Tr. Rev., vol. 49, pp. 825-829, 6 ill.)
Description of Mill No. 3 at Mineville, Essex Co., N.Y., operated by Witherbee, Sherman & Co., magnetic separation of Ball-Norton belt type.

Hansell, N. V.
Iron mining beyond the Arctic circle. 1911. (Iron Age, vol. 87, pp. 608-615, 14 ill.)
Concentrating and briquetting operations in the Sydvaranger district in northern Norway, using Gröndal magnetic separators. Iron percentage of ore varies between 30 and 38 per cent.

Henry.
Les separateurs électro-magnétiques. 1911. (L'Electricien, vol. 41, pp. 305-309.)
Theory, design, and construction of separators for use in the electromagnetic concentration of iron ores.

McKenzie, G. C.
Ore dressing and metallurgical laboratory. 1911. (Can. Dept. Mines, Mines Branch, Ann. Rept., pp. 58-83.)
Analyses and results of tests of magnetic concentration of Canadian iron ores.

Magnetic concentration and briquetting. 1911. (Min. and Sci. Press, vol. 102, p. 625.)
Brief paragraph of application of Gröndal process to low-grade magnetite ores of central Sweden.

Nassmagnetische Aufbereitung schwachmagnetischer Erze. 1911. (Stahl und Eisen, vol. 31, pp. 1127-1129.)
The wet magnetic preparation of weak magnetic ores by an Ullrich separator.

Nicou, Paul.
Etude sur les minerais de fer scandinaves. 1911. (Ann. des Mines Men., vol. 19, pp. 249-376, 2 inserts.)
Magnetic separation and briquetting, historical, general lay out of plants; separators, Gröndal, Landen Josephson, Monarch, Fröding, Forsgren, Eriksson, Vulcanus, Lundberg, Holmberg, Ekman, Markman; personnel, costs, results. Pp. 303-316: briquetting; pp. 316-351: magnetic preparation of ore from the north of Norway including Dunderland, Bogen, Salangen, and Sydvaranger.

Ostwald, H.
Die magnetische Anreicherung von Eisenerzen nach dem Gröndal-Verfahren. 1911. (Stahl und Eisen, vol. 31, pp. 22-29.)
Magnetic concentration of iron ores by the Gröndal process: progress of, process, amount of ore treated, description of Gröndal separator costs, Hill.

Petroff, B. A.
Bericht über die Versuche der elektromagnetischen Aufbereitung und der Brikettierung der Eisenerze von Blagodatuafa (Ural) in Russian. 1911. (Gorni J., 1911, Maiheft, pp. 125-166.)
Notes on the experiments in electromagnetic separation and briquetting of iron ore at Blagodatuaga, Ural, in Russia.

Some results of magnetic separation at Dunderland. 1911. (Iron and Coal Tr. Rev., vol. 82, p. 506.)
The Ullrich wet method is used in these mines in Norway with success.

Stoltz, G. C.
The Cheever mines, Port Henry, N.Y. 1911. (Eng. and Min. Jour., vol. 92, pp. 809-812.)

Pp. 811: concentrating mills equipped to handle 700 tons of crude ore per day, Buchanan jaw crusher, Ball-Norton drum cobber, Buchanan corrugated rolls, Buchanan drum cobber, Ball-Norton belt separator.

UGGLAS, L. R.
Magnetisk anrikning af järnmalm i Förenta Staterna. 1911. (Beihang till Jernkontorets Ann., vol. 8, pp. 657-684.)
Magnetic concentration of iron ores in United States, including Mineville, N.Y.; Cheever Iron Ore Company, N.Y.; Benson Mines, N.Y.; Lebanon, Pa.

Vellykkede resultater med magnetisk separation av malmer fra Dunderland. 1911. (Teknisk Ugeblad, vol. 29, p. 149.)
Results of magnetic separation of ore at the Dunderland Iron Ore works, Sweden, with Ullrich separator.

WHITFIELD, R. C. V.
Magnetic ore dressing. 1911. (Cassier's Mag., vol. 40, pp. 533-538.)
Classifies iron ores which can be magnetically treated, outlines process followed by Ball-Norton, belt, Edison, and Wetherill separators.

WOODBRIDGE, D. E.
The Sydvaranger iron mines. 1911. (Eng. and Min. Jour., vol. 92, pp. 260-264.)
Pp. 262-263: use of Gröndal magnetic separator on low-grade magnetite ores on the shores of the Arctic ocean.

1912—Dressing of Siegerland siderite. 1912. (Stahl und Eisen, vol. 32, pp. 1949-1955.)
Treatment of siderite with electromagnetite separators, Forsgren and Humboldt types. Analyses of magnetites, concentrates, etc.

GRÖNDAL, G.
Berättelse öfver vid Herräng gjorda försök att reducera järnmalm. 1912. (Jernkontorets Ann., vol. 67, pp. 158-179, 8 plates.)
Communication on the attempt made at Herräng to reduce iron directly from magnetic iron ore.

HAMILTON, J. W. H.
Progress in the preparation of iron ores. 1912. (Iron Age, vol. 90, pp. 1034-1039.)
Coarse crystalline ores can best be concentrated by dry methods, at low cost. The Witherbee, Sherman and Company plants at Mineville, N.Y., work on coarse magnetites, using dry magnetic separation. The Sydvaranger mill in Norway uses the wet magnetic Gröndal method for low-grade, fine-grained magnetite.

HANSELL, N. V.
The concentration of iron ores. 1912. (A.I.M.E. Bull. 72, pp. 1497-1517, disc., Bull. 75, pp. 529-532.)
P. 1508: magnetic separation. Application of cobbing and dry or wet magnetic separation.

LOUIS, H.
The magnetic concentration of iron ores. 1912. (Jour. West of Scotland Iron and Steel Inst., vol. 19, pp. 206-236, disc. pp. 236-244; abst., Iron and Coal Tr. Rev., vol. 84, pp. 836-838, 18 fig.)
Theory, examples of magnetic iron ores, design of separators, results obtained.

McKENZIE, G. C.
The magnetic iron sands of Natashkwan, County of Saguenay, Province of Quebec. 1912. (Can. Dept. of Mines, Mines Branch, Rept. 145, 1912; abst., Jour. Iron and Steel Inst., vol. 88, p. 520.)
Describes magnetic separation test on the magnetic iron sands of Natashkwan. Concentration can be best accomplished by the use of the wet magnetic separator of the Gröndal type. Gives details of a plant and process suitable for carrying out the concentration of these sands on a paying basis.

Magnetische Anreicherung von Ural Erzen in Herräng (Schweden). 1912. (Stahl und Eisen, vol. 32, pp. 822-826.)
Magnetic separation of Ural ores at Herräng, Sweden. Tests, apparatus, analyses, etc.

The Sydvaranger iron mines in Norway. 1912. (Elec. Rev., vol. 70, pp. 345-347.)
Treatment of low-grade ore with complete Gröndal magnetic separator process.

UDHAUG, A.
The Sydvaranger iron mines. 1912. (Iron and Coal Tr. Rev., vol. 84, pp. 161-163.)
Describes magnetic separation plant.

Vogt, J. H. L.
Magnetisk separation av titanholdig jernmalm ved Rodsand, Nordmore. 1912. (Teknisk Ugeblad, vol. 30, pp. 110-111.)
Magnetic separation of titaniferous iron ore at Rodsand, Nordmore.

Woodbridge, D. E.
Beneficiating Lake iron ores. 1912. (Eng. and Min. Jour., vol. 93, pp. 222-223.)
Brief mention of use of Gröndal wet magnetic separator plant at Moose mountain in the Georgian Bay region.

Woodbridge, D. E.
Mining and concentrating the Sydvaranger iron ores. 1912. (Eng. Mag., vol. 43, pp. 9-21.)
The ore is crushed in Gröndal ball mills and concentrated by Gröndal magnetic separators.

1913—Bartsch, J. W.
Anreichen, Brikettieren und Agglomerieren von Eisenerzen und Gichtstaub. (Concentrating, briquetting and agglomerating iron ores and flue dust.) 1913. (Stahl und Eisen, vol. 33, pp. 1238-1244; abst., Jour. Iron and Steel Inst., vol. 88, p. 522.)
Practice in Sweden has brought the knowledge of briquetting and concentrating magnetic ores to a satisfactory point. For lean magnetic ores the Wetherill process was used, the ores being dry. Now, however, wet ores can be separated magnetically.

Coleman, A. P.
The Moose Mountain iron range. 1913. (Can. Min. Jour., vol. 34, p. 573.)
Brief description of concentration of the magnetite by the Gröndal method.

Electromagnetic ore concentration by the Ullrich separators. 1913. (Min. Jour., vol. 103, pp. 1022-1026.)
Detailed illustrated discussion of design and application of Ullrich separators for magnetic iron ore.

Kellogg, L. O.
An iron concentrator of unusual design. 1913. (Eng. and Min. Jour., vol. 96, pp. 243-245.)
The Mount Summit Ore Corporation owns a magnetite deposit in the Hudson highlands. The concentrating plant employs permanent magnets which deflect the iron from a falling curtain of ore.

Kranfeldt, P.
Electromagnetic ore concentration by the Ullrich separator. 1913. (Can. Min. Jour., vol. 34, pp. 703-707, vol. 46, pp. 596-598.)
Theory and design of separators; description of Ullrich separator; table of practical results of use of Ullrich machines.

Magnetic separation of minerals. 1913. (Met. and Chem. Eng., vol. 11, p. 297.)
Campbell system of magnetic separation of pyrite.

Nason, S. L.
Witherbee-Sherman No. 3 magnetic mill. 1913. (Eng. and Min. Jour., vol. 96, pp. 959-962.)
This mill at Mineville, N.Y., handles a magnetite ore running 40 to 50 per cent. iron. Dry crushing and magnetic separators are used. Of the separators three types are employed, drum machines, pulley machines, and belt machines.

Schennen, H., and Jungst, F.
Lehrbuch der Erz- und Steinkohlen Aufbereitung, 1913, F. Enke Stuttgart, pp. 728.
Pp. 298-321: general theories of magnetic separation of ores, types of separators including Buchanan, Gröndal, Forsgren, Ullrich, Ball-Norton, Wetherill, Edison, Humboldt.

Singewald, J. T.
The titaniferous iron ores in the United States. 1913. (U.S. Bur. Mines Bull. No. 64, pp. 145.)
Pp. 17-24: elimination of titanium by magnetic concentration. Results of tests on Pine Lake, Chaffey, Heindalen, Loforten Island, St. Lawrence, and United States ores.

1914—Beielstein, A.
Aufbereitung und Brikettierung von Eisenerz in Skandinairen. 1914. (Stahl und Eisen, vol. 34, pp. 41-46, 100-105.)
Dressing and briquetting of iron ores in Scandinavia. Pp. 41-43: discussion of magnetite ores found; p. 44: plants in operation; p. 100: process of concentrating the ores and of briquetting the concentrates.

Briquetting ore at Mayville, Wis. 1914. (Iron Age, vol. 94, p. 1258.)
A mixture of 60 per cent. of briquettes (made by the Gröndal process) and 40 per cent. of Lake ore, instead of 60 per cent. crude Mayville ore and 40 per cent. of Lake ore showed a reduction in coke consumption of 200 pounds per ton of pig iron, while the production of iron has been increased by 30 to 40 tons per day.

Comstock, H.
Concentrating at Barton Hill. 1914. (Iron Tr. Rev., vol. 55, pp. 253-256.)
Magnetic separation of ore by Witherbee, Sherman & Co., Mineville, N.Y., from mine, abandoned for 22 years because of low grade of ore. Describes separating plant.

Holmgren, G. H.
Om jarnmalmsfälten i Förenta Staternas östra gruvdistrikt. 1914. (Beihang till Jernkontorets Ann., vol. 15, pp. 221-246.)
Iron ore preparation in the eastern part of the United States. Magnetic iron ore of the Lake Champlain district, magnetic separation with Ball-Norton drum separators.

Le Fevre, S.
Application of electricity to mines and mills of Witherbee, Sherman & Co., Inc., Mineville, N.Y. 1914. (A.I.M.E. Bull. No. 90, pp. 1144-1157.)
Includes (pp. 1148-1150) description of Ball-Norton type of magnetic separator.

Magnet to remove iron from ore. 1914. (Eng. and Min. Jour., vol. 97, p. 442.)
Photograph and brief description of magnet used to remove iron from the products of the crushing plant at Miami mill at Miami, Ariz.

Magnetic separation plant at the Rodsand iron mines in Norway. 1914. (Iron and Coal Tr. Rev., vol. 88, p. 26.)
Gröndal magnetic separation plant of two-ball mills and five sets of separators.

Pellet, J. S.
Witherbee-Sherman No. 4 magnetic separator. 1914. (Eng. and Min. Jour., vol. 97, pp. 549-553.)
Description of concentrating plant at Mineville, N.Y., using three part separation, preliminary roughing, close sizing, and fine crushing, and making a 64 per cent. product from a 30 per cent. ore.

Rate of belt travel in magnetic separators. 1914. (Eng. and Min. Jour., vol. 97, pp; 279-280.)
Experiment conducted at a Prussian magnetic separating plant at Mechernich showed that with electric current at 1,000 watts, at a velocity of 100 per minute, only the magnetite was attracted; at 70 m. per minute, the rhodonite was slightly influenced, at 50 m. per minute, the rhodonite was entirely removed; and at 30 m. per minute. the blende was completely extracted.

1915—Clark, I. C.
Electromagnetic ore separation. 1915. (Eng. and Min. Jour., vol. 99, pp. 523-528.)
Action of magnetic flux; magnetic properties of metals; electromagnetic separators; attraction of minerals; feeding devices; removal of products; minerals amenable to magnetic separation, Mineville, N.Y.; magnetic mills, Hope, N.J.; separation of magnetite from impurities, of blende from pyrite, of magnetic blackjack from pyrite.

Hoefinghoff, H.
Aufbereitung von Eisenerzen. (Preparation of iron ore.) 1915. (Mont. Rundschau, vol. 7, pp. 472-474, 602-605.)
Describes modern practice in magnetic concentration, briquetting, and smelting of briquettes of iron ore.

Hood, B. B.
Concentrating plant of the Moose Mountain, Ltd. 1915. (Eng. and Min. Jour., vol. 99, pp. 973-976.)
Milling methods of the magnetic iron ore of the Moose Mountain, Ltd., at Sellwood, using Ball-Norton magnetic separators.

Iron ores produced by Moose Mountain Ltd., Ontario. 1915. (Can. Min. Jour., vol. 36, p. 862.)
Brief outline of concentrating and briquetting process by which magnetite 38 per cent. iron, is raised to approximately 63 per cent. iron.

New magnetic iron ore separator. 1915. (Iron Age, vol. 96, p. 577.)
Method for the magnetic separation of iron ores while submerged under a carrying liquid, U.S. patent 1,146,140 of F. B. Dutton and B. E. McKechnie, assigned to Pennsylvania Steel Co.

Preparing pyritiferous blende for magnetic separation. 1915. (Eng. and Min. Jour., vol. 99, p. 284.)
U.S. pat. 1,103,081, roasting the pyrite in a muffle or shaft without air at temperatures ranging from 600° to 800°C.

Rapid electromagnetic separator. 1915. (Min. Jour., vol. 108, p. 118; Min. Mag., vol. 13, p. 50; Iron and Coal Tr. Rev., May 28th; Engineering, vol. 119, p. 118.)
Machine for use with feebly magnetic ores.

Shapira, S.
Magnetic concentration mill at Mount Hope, N.J. 1915. (Eng. and Min. Jour., vol. 99, pp. 559-565.)
Detailed illustrated description of Empire Steel and Iron Company plant, using Ball-Norton magnetic separating machines of the belt, drum, and pulley type, and making finished concentrates, middlings for retreatment and tailings from New Jersey iron ores.

Wiard, E. S.
The theory and practice of ore dressing, 1915, McGraw-Hill Book Co., New York, pp. 426.
Pp. 401-412: magnetic separation, Wetherill magnetic separators, International magnetic separator, Ding's magnetic separator.

Wright, C. W.
Magnetic separation in Sardinia. 1915. (Eng. and Min. Jour., vol. 100, pp. 911-913.)
Description of process using Ullrich electromagnetic separation, at the Gennamari Engurtosu mine on a blende siderite ore.

Wuster, R.
Uber die Aufbereitung von nassen Erzen auf elektromagnetischem Wege. 1915. (Dingler's Poly. Jour., vol. 330, pp. 1-5.)
Separation of wet ores electromagnetically by the Humboldt system.

1916—Jobke, A. F.
Improved magnetic separator. 1916. (Eng. and Min. Jour., vol. 102, pp. 817-819.)
The Jobke machine utilizes several magnetic zones in a given field, all of the same length of air gap. It is said that time is not a factor influencing the rapidity of magnetizing ore particles, and the overshooting of a magnetic zone by a particle must be attributed to inertia and not to slowness of magnetic action.

Larson, H.
Om järnmalmsanrikning i östra delen av Förenta Staterna och därvid använda maskiner. 1916. (Beihang till Jernkontorets Ann., vol. 17, pp. 17, 37-79.)
Iron ore concentration in the eastern parts of the United States and apparatus used including Blakes and Gates drums, rollers, screens, separators, travelling belts.

(Metallurgia Italiana, December, 1916, pp. 758-767.)
Gives an account of the magnetic concentration of titaniferous magnetites and ilmenite in Quebec.

Ralston, O. C.
The control of ore slimes. 1916. (Eng. and Min. Jour., vol. 101, pp. 763-769.)
Pp. 765-769: essentials of the Murex magnetic process used for treating finely-ground magnetic material such as magnetite or pyrrhotite.

Smelting New Zealand iron sand. 1916. (Engineering, vol. 122, p. 583.)
Iron sand and powdered coal are mixed and "coked." The "ferro-coke" is fed into the blast furnace with limestone and sinter.

1917—Norton, S., and Ferre, S. L.
The magnetic concentration of low-grade iron ores. 1917. (A.I.M.E. Bull., vol. 122, pp. 149-169.)
Development and application of the Ball-Norton wet and dry processes of separation of magnetic iron ores.

1918—La concentration magnétique des minerais de fer à Mineville (E-U). (The magnetic concentration of the iron ore of Mineville.) 1918. (Génie Civil, vol. 73, pp. 495-496.)
Describes the crushing and concentrating installations, giving diagrams of the magnetic separators.

Henry, E. C.
Magnetic concentration of iron ores at Mineville, N.Y. 1918. (Eng. and Min. Jour., vol. 105, pp. 912-914.)
Magnetite iron ores containing about 30 per cent. Fe are concentrated magnetically at Witherbee, Sherman & Company's mill. Products: concentrates 65 per cent. Fe, tailings 5 per cent. Fe. Flow sheet.

1919—Aubel, V. W.
Titaniferous iron sands of New Zealand. 1919. (A.I.M.E., Bull. 153, pp. 2081-2095; disc., Bull. 155, pp. 3009-3015; Trans. A.I.M.E., vol. 63, pp. 266-280, disc. pp. 280-288; Iron Tr. Rev., vol. 65, pp. 1388-1391.)
Describes various attempts at magnetic separation, briquetting, and smelting of these sands which average 55 per cent. metallic iron. In the end a mixture of raw sand, coke, limestone, and silica rocks was charged and no apparent difference was noted in the behaviour of the furnace.

Bonardi, J. P.
Magnetic concentration of pyrrhotite ores. 1919. (Chem. and Met. Eng., vol. 20, pp. 266-270.)
Experiments and tests as to costs and quality made with a Wetherill type magnetic separator on pyrrhotite ore.

Concentration of iron ore at Mineville, N.Y. 1919. (Eng. and Min. Jour., vol. 107, p. 1171.)
A change in the equipment of the Witherbee, Sherman and Company's mill has made it possible to re-treat tailings, so that they contain on an average only 5 to 6 per cent. iron.

Escard, Jean.
La concentration et la triage électromagnétiques des minerais de fer et des déchets métallurgiques. (Electromagnetic concentration and separation of iron minerals and metallurgical waste.) 1919. (Génie Civil, vol. 75, pp. 603-607, 622-627, 648-652.)
Gives particulars of constructionand records of operation of Edison, Rowland, Waterhill, Humboldt, Negreanu, Blake, Steinert-Kertler, Gröndal, and Luther magnetic separators.

Pulligny, L. D.
Note sur les minerais de fer titanifères des Etats-Unis. (Note on the titaniferous ores of the United States.) 1919. (Ann. des Mines, vol. 7, pp. 125-126.)
Believes that magnetic concentrates of titaniferous ores may be reduced in the blast furnace. The electric furnace offers another possibility.

Young, G. T.
Working adjustments of the Wetherill magnetic separator. 1919. (Eng. and Min. Jour., vol. 107, pp. 1156-1158.)
Considers pole distance, amperage speed of take-off belt, and thickness and uniformity of feed.

1920—Concentration of magnetite ore. 1920. (Min. and Sci. Press, vol. 121, p. 122.)
Briefly describes work of cobbing, crushing, and sintering ores of eastern Mesabi range. Financial value of the method is yet to be determined.

Davis, E. W.
The future of the Lake Superior district as an iron ore producer. 1920. (Minn. Sch. of Mines Exp. Sta., Bull. 7, pp. 18.)
Pp. 11-17: explains magnetic concentration and its experimental application to eastern Mesabi ores.

Davis, E. W.
New era dawns in ore industry. 1920. (Iron Tr. Rev., vol. 67, pp. 301-304.)
Magnetic concentration is being tried on the eastern Mesabi magnetites. The hard rock is first crushed to about 3-inch size and is passed over a magnetic cobber. The process of crushing and cobbing is repeated until the ore is one-quarter inch size, and this is crushed in wet mills until it will pass 100-mesh screen. This is passed through magnetic log-washers and later sintered, the clean coarse sinter being sent to the furnace.

Durrer, R.
Uber die Verhüttung von Titaneisensand. (Smelting titaniferous iron sand.) 1920. (Stahl und Eisen, vol. 40, pp. 938-941.)
Gives results of experiments on smelting New Zealand iron sands.

HESKETT, J. A.
Utilization of titaniferous iron ore. 1920. (Min. and Met., No. 162, pp. 29-30.)
Experiments with New Zealand iron sands proved that pig iron produced from titaniferous ore will not grain out as will other iron of similar analysis.

HESKETT, J. A.
The utilization of titaniferous iron ore in New Zealand. 1920. (Jour. Iron and Steel Inst., vol. 101, pp. 201-214.)
A U-pipe hot blast was installed and a mixture of eight parts of sand to one part of coal was used. The sand and coal were ground to an impalpable powder in a Fuller-Lehigh mill. It was then briquetted in an ovoid briquette machine and carbonized. The resultant briquette contained 50 per cent. of iron. Flushing both slag and iron through the tap-hole at short intervals will overcome the titaniferous accretions, but this occasions considerable loss of iron.

HORE, R. E.
Utilization of Ontario iron ores. 1920. (Can. Min. Jour., vol. 41, pp. 796-797.)
Mr.James W. Moffat has designed a metallizing furnace which gives a hot product easily finished in the electric furnace. Magnetic concentrates can be used without sintering or briquetting.

HUBBELL, A. H.
The Replogle iron mine near Wharton, N.J. 1920. (Eng. and Min. Jour., vol. 110, pp. 658-664.)
Dry magnetic separation is carried out and the tailings are concentrated in a wet mill. The wet mill is used because of the presence of a considerable amount of martite.

KNOBEL, H. E.
The use of Ontario iron ores for Canadian furnaces. 1920. (Can. Inst. Min. and Met., Bull. 103, pp. 872-879.)
At Moose Mountain mine banded magnetites assaying 37¼ per cent. iron are magnetically concentrated to a product, 63 per cent.iron. Nearly all Canadian iron ores require beneficiation.

Magnetite town on eastern Mesabi to be known as Argo. 1920. (Iron Tr. Rev., vol. 66, pp. 436-437.)
Experiments with peat as a fuel for sintering the magnetite concentrates are being made.

O'CONNOR, J. J.
Beneficiation of low-grade ores on the Minnesota ranges suggests similar utilization of Ontario ores. 1920. (Can. Min. Jour., vol. 41, p. 488.)
Everything that is being done on the eastern Mesabi range on magnetic separation can be repeated in Ontario.

AVIS, J. L.
Pig iron from black sands. 1921. (Iron Age, vol. 108, p. 83.)
Binder (not named) removes chromium and titanium from the black sands at Sedro Woolley, Wash. Satisfactory pig iron has been produced and steel and grey iron castings have been made.

1921—AVIS, J. L., JR.
Making pig iron and steel from Pacific Coast black sands. 1921. (Iron Tr. Rev., vol. 69, pp. 810-812.)
Describes experiments by the New Era Iron and Steel Corporation at Sedro Woolley, Wash. Briquetted ore, coke, and limestone are charged in the blast furnace in proportions of 47, 47, and 5 per cent., respectively.

Concentrating magnetite ore. 1921. (Min. and Sci. Press, vol. 123, pp. 769-770.)
Gives brief description of magnetic log-washer invented by Mr. Edward W. Davis. Describes preliminary work in erecting the plant on the eastern Mesabi range.

DAVIS, E. W.
Magnetic concentration of iron ore, 1921, Univ. of Minn. Exp. Sta., Bull. 9, pp. 138.
Contents include: (I) Physical structure of typical iron ores, pp. 7-11; (II) standard ore dressing practice, pp. 12-21; (III) magnetism, pp. 22-29; (IV) the oxides of iron, pp. 30-34; (V) magnetic roasting, pp. 35-49; (VI) principles of magnetic concentration, pp. 50-53; (VII) magnetic concentrating machinery, pp. 54-85; (VIII) magnetic concentration tests on natural magnetite ores, pp. 86-111; (IX) magnetic concentration tests on non-magnetic ores rendered magnetic by roasting, pp. 112-117; (X) standard testing methods for magnetic iron ores, p. 118-124; (XI) plant flow sheets for iron ore concentration, pp. 125-132; (XII) conclusions and general survey, pp. 133-138.

Goodwin, W. M.
Smelting of titaniferous iron ores. 1921. (Trans. Royal Can. Inst., vol. 13, pp. 35-49.)
It has been demonstrated that with the use of a slag consisting of titania, silica, and alumina, titaniferous iron ores can be satisfactorily reduced to pig iron in the electric furnace. The evidence indicates that the process is applicable to the blast furnace. Gives numerous references to the literature of smelting titaniferous ores.

Hain, A. J.
Tapping the nation's great reserves of lean iron ores. 1921. (Iron Tr. Rev., vol. 68, pp. 33-37, 44.)
Describes plant for crushing and concentrating the iron ores of the eastern Mesabi range. In the sintering the introduction and mixing of the fuel is done while the concentrate is still fluid before it goes to the filter.

Hain, A. J.
The utilization of lean iron ores. 1921. (Iron and Steel of Can., vol. 4, pp. 35-38.)
Describes progress in utilization of lean magnetites of eastern Mesabi range by grinding, magnetic concentration, and sintering.

Kreutzberg, E. C.
Developing North Jersey iron ores. 1921. (Iron Tr. Rev., vol. 69, pp. 1207-1211, 1285-1289.)
Second article describes particularly the magnetic concentrating plant at the Beach Glen mill. The ore is washed after the first crushing.

Die magnetische Erzaufbereitung. (Magnetic concentration of ore.) 1921. (Bergbau, vol. 34, pp. 1201-1209.)
Explains various types of magnetic separators.

1922—Electromagnetic separation. 1922. (Chem. Tr. Jour., vol. 61, pp. 387-388.)
Discusses pulley type of separator and the cobbing separator. The apparent simplicity of construction is deceptive. Describes advantages of large diameter pulleys.

Goodwin, W. M.
Method of smelting titaniferous iron ore. 1922. (Can. Hon. Advisory Council for Sci. and Ind. Research, Ottawa, rept. No. 8, pp. 25.)

Hille, F.
The Mattawin iron range. 1922. (Can. Min. Jour., vol. 43, pp. 872-876.)
This range is in Western Ontario. Gives an account of the Gröndal magnetic separation process. Estimates that a plant that treats 3,000 tons of raw ore would cost about $600,000.

McKenzie, G. C.
Canada's iron ore problem: beneficiation of Ontario iron ores. 1922. (Can. Min. Jour., vol. 43, pp. 482-483; Iron and Steel of Can., vol. 5, pp. 136-139.)
Concludes that of the various processes of beneficiation, the only two to be seriously considered are magnetic separation and calcining of siderites.

Official conference on Ontario iron ore. 1922. (Can. Min. Jour., vol. 43, pp. 446-448; Iron and Steel of Can., vol. 5, pp. 117-119.)
At a meeting of representative interests, the processes and cost of beneficiation and the market for beneficiated ores were discussed. Concluded that the present methods of beneficiation were satisfactory and nodulizing and briquetting were recommended.

Wade, H. H.
Magnetic log-washers in iron ore concentration. 1922. (Eng. and Min. Jour., vol. 113, pp. 769-771.)
By adding magnets to the bottom of the trough of an ordinary log-washer a machine is made which will concentrate finely crushed magnetite ores. This was developed at the Minnesota School of Mines Experiment Station for use on ores of the eastern Mesabi range.

3. Treatment and Reduction of Titaniferous Iron Ores and Their Occurrence in Canada

1863—RILEY, E.
Smelting titaniferous ores. (Jour. Chem. Soc., vol. 16, 1863, p. 387.)

1866—HUNT, T. S.
Iron and iron ores. (Geol. Surv. Can., Rept. of Progress, 1866-69, pp. 245-304.)
P. 252: deals briefly with behaviour of titanic ores in the blast furnace; p. 257: gives analysis of magnetic iron, found on the Rideau canal in South Crosby, Ont., containing 9.8 per cent of titanic acid; p. 260: describes the magnetic iron ore with 34.3 per cent. of titanic acid as found at the Rapid river; pp. 266-269: describes the occurrence and method of treatment of iron sands containing titanium.

1873—HARRINGTON, B. J.
Notes on the iron ores of Canada and their development. (Geol. Surv. Can., Rept. of Progress, 1873-74, pp. 192-259.)
Pp. 249-251: manufacture of iron from titanic iron ore, amount of charcoal consumed, dimensions of Hall furnace.

1874—FORBES.
(Jour. Iron and Steel Inst., 1874, No. 1, p. 132.)
States that in 1874 it was common practice in Sweden to add 10 per cent. of titaniferous ores to the charge to reduce sulphur.

1883—BOWRON, W. M.
Practical metallurgy of titaniferous ores. 1883. (Trans. A.I.M.E., vol. 11, pp. 159-164.)
Deals with treatment of titaniferous iron ores in the blast furnace.

1888—HOFFMANN, G. C.
Annotated list of minerals occurring in Canada. (Geol. Surv. Can., Ann. Rept., 1888-89, vol. 4, pp. 1-67T.)
P. 39T: ilmenite in parish of St. Urbain, at Baie St. Paul and in Chateau Richer and Rawdon. Associated with labradorite rocks, ilmenite has been observed near the mouth of Rapid river, on the Saguenay river, on shores of Lake Kenogami and some other localities in Province of Quebec. P. 216: occurrence of rutile in Nova Scotia, etc.

1890—ELLS, R. W.
Report on mineral resources of the Province of Quebec. 1890. (Geol. Surv. Can., vol. 4, pp. 1-159K.)
P. 8K: titaniferous magnetic iron ores along the lower St. Lawrence, below Quebec. Pp. 14-15K: at Baie St. Paul, below Quebec. Titaniferous magnetic iron with 34 to 30 per cent. of titanic acid near the mouth of the Rapid river. Titaniferous iron sands at the mouth of the Moisie river. Ilmenite deposits at St. Jerome and St. Lin. P. 18K: titanic ores of Sutton and Brome and of the Chaudière river, Beauce.

ROSSI, A. J.
Titanium in blast furnaces. 1890. (Jour. Am. Chem. Soc., vol. 12, pp. 91-117.)
P. 97: occurrence of titaniferous iron ores in Canada in the Baie St. Paul ores, in Moisie River sands, etc. Pp. 103-107: possibilities of smelting successfully titaniferous iron ores in the blast furnace.

1892—ROSSI, A. J.
Titaniferous ores in the blast furnace. 1892-3. (Trans. A.I.M.E., vol. 21, pp. 832-864; disc., pp. 864-867.)
Design of blast furnaces; theory and practice of titanite slags; results of experiments with smelting of ores in the blast furnace.

1896—ROSSI, A. J.
Smelting of titaniferous ores. 1896. (Iron Age, vol. 57, pp. 354-356, 464-469.)
Reviews different methods of treatment of titaniferous ores; gives illustrated description of blast furnaces used in smelting of titaniferous ores and blast furnace tests. Concludes that in running a furnace under special conditions of temperature and pressure of blast, no troubles have been experienced from titanium deposits. Most economical results are obtained by introduction of magnesia to an important extent into composition of the slag, with alumina and lime.

1899—KEMP, J. F.
Brief review of titaniferous magnetites. 1899. (Sch. Mines Quart., vol. 20, pp. 322-356; vol. 21, pp. 56-65.)
Pp. 326-333: describes the titaniferous iron ores in Canada: the Chaffey ore, the Pine Lake ore, the Eagle Lake ore, and the Norton ore. Describes various titaniferous iron sands; sands occurring on the north shores of the St. Lawrence river and at Moisie bay near the mouth of the Moisie river.

POPE, F. J.
Investigation of magnetic iron ores from Eastern Ontario. 1899. (Trans. A.I.M.E., vol. 29, pp. 372-405.)
Pp. 377-379: describes the magnetic titaniferous ore bodies of the gabbro type occurring in the Chaffey iron mine in the County of Leeds, the Pine Lake ore body in Victoria county, and the Eagle Lake mine in Frontenac county. P. 402: elimination of titanic oxide from titaniferous magnetite by magnetic concentration.

1900—KEMP, J. F.
Ore deposits of United States and Canada, 1900, New York and London, Scientific Publ. Co., pp. 481.
P. 172: occurrence of titaniferous iron ores in Canada at St. Lawrence on the Saguenay river, in Quebec and in Ontario.

ROSSI, A. J.
Manufacture of titanium and its alloys. 1900. (Min. Ind., vol. 9, pp. 715-730.)
Reduction of titaniferous iron ores by means of aluminum in the electric furnace. Details of working table showing the composition of a number of alloys produced. "Concentration" of titaniferous iron ores.

ROSSI, A. J.
Pig iron made from titaniferous ores. 1900. (Eng. and Min. Jour., vol. 69, p. 284.)
Deals with the qualities of pig iron obtained from titaniferous ores by reduction with carbon at the temperature of the blast furnace.

1901—MILLER, W. G.
Iron ore fields of Ontario. 1901. (Jour. Can. Min. Inst., vol. 4, pp. 265-283.)
Refers briefly to deposits of titaniferous magnetite, which occur from the area bordering the Rideau canal in the most eastern part to the Rainy River district in the west.

OBALSKI, J.
Notes on magnetic iron sand of the north shore of the St. Lawrence, 1901. (Jour. Can. Min. Inst., vol. 4, pp. 91-98.)
P. 92: states that the black sand found near Moisie contains 16 per cent. TiO_2 and 55.23 per cent. Fe.

1902—HILLE, F.
Iron deposits of Western Ontario and their genesis. 1902. (Jour. Can. Min. Inst., vol. 5, pp. 49-61.)
P. 59: mentions the occurrence of large titaniferous iron, or ilmenite deposits of Greenwater lake.

ROSSI, A. J.
Metallurgy of titanium. 1902. (Jour. Franklin Inst., vol. 154, pp. 241-261; Trans. A.I.M.E., vol. 33, pp. 179-197.)
Occurrence, constitution, behaviour in the blast furnace, and reduction in the electric furnace.

1903—COLEMAN, A. P.
Sudbury nickel deposits. 1903. (Ont. Bur. Mines, vol. 12, pp. 235-303.)
P. 281: titaniferous iron ore was found in small quantities at the Murray mine.

KEMP, J. F.
Ore deposits of United States and Canada, 1903, New York, Eng. and Min. Jour., 5th ed., pp. 481.
P. 172: titaniferous iron ores are of enormous size on lower St. Lawrence, on Saguenay river; smaller masses occur in Quebec north of Montreal, and in Ontario north of Kingston.

ROSSI, A. J.
Manufacture of ferro-alloys in general and of ferro-titanium in particular in the electric furnace. 1903. (Electrochem. Ind., vol. 1, pp. 523-526.)
P. 526: note on reduction of titaniferous ores by smelting with addition of carbon in the electric furnace.

WELLS, J. W.
Magnetic concentration of iron ores. 1903. (Ont. Bur. Mines, vol. 12, pp. 322-337; Jour. Can. Min. Inst., vol. 6, p. 20.)
P. 325: concludes from his experiments that in some titaniferous ores, the titanium may be elimated, as ilmenite is not so magnetic as magnetite. In pure ilmenite, it is impossible to reduce the percentage of titanium by magnetic concentration. P. 333: iron bearing sands, from the north shore of the St. Lawrence river, were passed through the separator and the ilmenite thus eliminated from magnetite.

1904—HULST, N. P.
Titaniferous iron ores. 1904. (Iron Tr. Rev., vol. 37, pp. 92-95; abst., Jour. Iron and Steel Inst., vol. 67, p. 539.)
Gives details on occurrence of titaniferous ores: hematite containing up to 3.17 per cent. of TiO_2 from the Haycock mine near Ottawa, Canada, and high phosphorus titaniferous magnetite ores with 9.8 per cent. TiO_2 in South Crosby. Describes methods of concentrating by means of magnetic separation and by gravitation methods. Reviews various reduction experiments with titaniferous ores in the blast furnace and points out relative infusibility of the slag.

HUPPERTZ, W.
Versuche über die Herstellung von Titan und Titanlegierungen aus Rutil und Titanaten im elektrischen Ofen. 1904. (Metallurgie, vol. 1, pp. 362-366, 382-385, 404-417, 458-462, 491-504.)
Detailed illustrated description of reduction experiments with rutile and titanites in the electric furnace. TiO_2 was reduced by means of carbon, calcium carbide, aluminum, and by electrolysis. It is pointed out that titanic acid in presence of iron cannot be reduced in the blast furnace by carbon or other reagents. Reduction occurs by means of nitrogen.

SNYDER, F. T.
Magnetic separation. 1904. (Jour. Can. Min. Inst., vol. 7, pp. 270-283.)
Points out difficulty of separating by magnetic separation, the titaniferous from the magnetite material.

1905—HAANEL, EUGENE.
Abstract of an address on electric smelting. 1905. (Jour. Can. Min. Inst., vol. 8, pp. 132-157.)
P. 153: difficulties in treating highly titaniferous ores in the blast furnace and successful treatment of iron sands containing 9.3 per cent. of titanic acid in the electric furnace by employment of an ultra-basic slag and extreme hot working.

LODYGUIRE, A.
Some results of experiments with reduction of titaniferous ores. 1905. (Trans. Am. Electrochem. Soc., vol. 7, pp. 157-163, disc. pp. 163-165.)
Gives analysis of the iron and slag obtained from the titaniferous ore from Canada used in his experiments made with a little electric furnace of his own design and having a capacity of 4.4 pounds at a charge. Description and methods of apparatus used are not given.

1906—COX, C. N., and LENNOX, L.
Tests of titaniferous slags. 1906. (Electrochem. and Met. Ind., vol. 4, pp. 490-499; abst., Jour. Iron and Steel Inst., vol. 75, p. 418.)
Concludes from his experiments that ores containing up to 5 per cent. of titanic acid can be smelted without difficulty in the blast furnace.

EVANS, J. W.
Some laboratory experiments in making steel directly from iron ores with the electric furnace. 1906. (Jour. Can. Min. Inst., vol. 9, pp. 128-142.)
P. 132: shows that the titanium contents in steel can be readily governed by reducing the quantity of lime in the charge.

1907—BENNIE, P. MCN.
Magnetic concentration of iron ores by the Gröndal process. 1907. (Jour. Can. Min. Inst., vol. 10, pp. 261-273.)
Gives results of tests made on the separation of titanium from ore, known as Moisie Beach sands, from the St. Lawrence river.

GIN, GUSTAVE.
Electrical reduction of titaniferous iron ores. 1907. (Trans. Am. Electrochem. Soc., vol. 11, pp. 291-298, disc. pp. 298-301.)
Occurrences of iron minerals containing titanic iron in Canada, etc. Smelting in the electric furnace; composition of charge.

HAANEL, EUGENE.
Report on experiments made at Sault Ste. Marie, in smelting of Canadian iron ores by the electro-thermic process, 1907, Ottawa, Mines Branch, Dept. of Interior, Canada, pp. 149.
P. 98: concludes as result of experiment made with a titaniferous iron ore containing 17.82 per cent. of titanic acid, that titaniferous iron ores containing up to 5 per cent. can be successfully treated by the electrothermic process.

1908—WILLMOTT, A. B.
Iron ores of Ontario. 1908. (Jour. Can. Min. Inst., vol. 11, pp. 106-123.)
P. 109: note on occurrence of considerable ore bodies of titaniferous magnetite, at the Old Chaffey mine, at the Matthews mine on the Rideau canal, near Gooderham, at Chapleau, etc.

1909—LEITH, C. K.
Iron ores of Canada. 1908-9. (Can. Min. Inst. Bull., vol. 2, pp. 75-89.)
P. 76: occurrence of titaniferous magnetites in Canada along the lower St. Lawrence river and in the Chaffey and Matthews mines of Lower Ontario. P. 85: magnetic sands high in titanium as exposed along the lower St. Lawrence river.

MALTITZ, E. VON.
Einfluss des Titans auf Stahl besonders auf Schienenstahl. 1909. (Stahl und Eisen, vol. 29, pp. 1593-1602.)
Briefly mentions possibility of obtaining titanium by reduction of titanic acid in the electric furnace or by the alumino-thermic process of Goldschmidt.

Titaniferous iron ore smelting at Bethlehem. 1909. (Iron Age, vol. 84, p. 1223; abst., Jour. Iron and Steel Inst., vol. 81, p. 611.)
Statement giving the experience with smelting of Tehawne titaniferous ore with positive results.

1910—HAANEL, EUGENE.
Iron ores of Canada. 1910. (Iron Ore Resources of the World, 11th Internat. Geol. Congr., Stockholm, vol. 2, pp. 721-743.)
P. 738: occurrence of titanic acid in Hull-Templeton town line iron ore deposits; p. 739: occurrence of titaniferous iron ores on lower St. Lawrence, along the Moisie river at Mingan, Bersimis, Tadousac, etc. Titaniferous iron ores north of Montreal at St. Jerome.

STANLEY, G. H.
Some experiments on smelting titaniferous iron ore in South Africa. 1910. (Iron and Coal Tr. Rev., vol. 80, p. 773; abst., Jour. Iron and Steel Inst., vol. 82, p. 452.)
Concludes from his experiments that titaniferous ore can be successfully smelted, though probably at the expense of a higher than normal fuel consumption.

STANSFIELD, ALFRED.
Tool steel direct from the ore in an electric furnace. 1910. (Jour. Can. Min. Inst., vol. 13, pp. 151-161.)
P. 160: occurrence of titaniferous iron ore containing 7.5 per cent. titanium at the Orton iron mine, in Hastings county.

1911—ADAMS, F. D.
Iron ore resources of the world. 1911. (Jour. Can. Min. Inst., vol. 14, pp. 215-235.)
P. 230: occurrence of enormous deposits of titaniferous magnetite in the western portion of the Bell Island deposits in Newfoundland.

BORCHERS, W.
Uber das reduzierende Verschmelzen oxydischer Erze im elektrischen Ofen. 1911. (Metallurgie, vol. 8, pp. 246-248; detailed abst., Jour. Iron and Steel Inst., vol. 84, pp. 552-553.)
Deals with reduction of titaniferous ores with carbon in an electric furnace.

NASON, F. L.
Some suggestive phases on iron mining industry of eastern North America. 1911. (Jour. Can. Min. Inst., vol. 14, pp. 259-273.)
P. 270: remarks on the difficulties in concentrating titaniferous iron ores. Points out that they are mechanical mixtures of magnetite and ilmenite and that therefore in magnetic separation titanium will be retained in the heads and magnetite lost in the tails.

WILLMOTT, A. B.
Undeveloped iron resources of Canada. 1911. (Jour. Can. Min. Inst., vol. 14, pp. 236-258.)

Pp. 241, 250-251: occurrence of titaniferous ores of the magmatic type in Quebec at Baie St. Paul, St. Jerome, etc., in Ontario in Bushnell, Nemogosenda, etc.

1912—DULIEUX, E.
Titaniferous ores and the magnetic sands on the north shore of the St. Lawrence. 1912. (Can. Min. Jour., vol. 33, pp. 450-451.)
Describes the gabbro mineralized with titano-magnetic particles as found on the Rapid river. Gives description and analyses of magnetic sands on the Moisie river, containing up to 8.43 per cent. of titanium.

EVANS, J. W.
Tool steel from titaniferous magnetite by Evans-Stansfield electric furnace process. 1912. (Trans. Can. Min. Inst., vol. 15, pp. 123-128.)
Describes the electric furnace used by Stassano for smelting Italian titaniferous magnetite; gives results of runs with titaniferous magnetite from the Orton mine in the electric furnace, showing possibility of making good tool steel direct from titaniferous ores, without addition of deoxidizers.

HENTON, H. M.
Titanium and its uses. 1912. (Min. and Sci. Press, vol. 104, p. 472.)
Briefly deals with reduction of high titanium ilmenites in the electric furnace by means of carbon.

PROST, E.
Cours de métallurgie, 1912, Paris and Liège, Béranger, pp. 888.
P. 842: mentions occurrence of titaniferous iron ores in Canada, at Baie St. Paul. Pp. 843-846: reduction of rutile by methods of Moissan (by means of carbon in the electric furnace), and by the electrolytic method of Borchers and Nuppertz; reduction of titaniferous iron ores in the electric furnace with use of an aluminum bath; reduction by means of carbon.

ROTHERT, E. H.
Process for titaniferous ores. 1912. (Iron Age, vol. 90, p. 183; abst., Jour. Iron and Steel Inst., vol. 87, p. 583.)
Announces a process for reducing titaniferous magnetic iron ores by means of a cheap fluxing method and a new style of furnace. No description is given.

STANSFIELD, ALFRED.
Electric smelting of titaniferous ores. 1912. (Can. Min. Jour., vol. 33, pp. 448-449.)
Deals briefly with the development of a process in which the reduction of titaniferous ores to metal, and the subsequent refining of the steel, is carried out in a single furnace.

WARREN, C. H.
Ilmenite rocks near St. Urbain, Quebec; a new occurrence of rutile and sapphirine. 1912. (Am. Jour. Sci., ser. 4, vol. 33, pp. 263-277.)
Describes the rocks consisting largely of titanic ore in Canada in the Parish St. Urbain. Describes their origin, structure, and chemical composition.

1913—BRUNTON, STOPFORD.
Some notes on titaniferous magnetite. 1913. (Econ. Geol., vol. 8, pp. 670-680.)
Concludes from his experiments carried out with ores from Newfoundland, Canada, etc., that titanium is not associated with iron in such a way that ilmenite and magnetite are formed, but the ore is composed of titaniferous iron mineral in which the amount of titanium varies. Magnetic concentration is not possible with titaniferous iron mineral of the composition of ilmenite.

DICKSON, C. W.
Ore deposits of Sudbury, Ontario. 1913. (Ore Deposits, A.I.M.E., No. 18, pp. 435-516.)
P. 457: minerals of the Sudbury nickel region. "Small masses of titaniferous magnetite (with as much as 18 per cent. of TiO_2) are at times found."

DULIEUX, E.
Iron resources of the province of Quebec. 1913. (Trans. Can. Min. Inst., vol. 16, pp. 351-370.)
P. 356-368: titano-magnetites in the Saguenay district, on the North Shore of the St. Lawrence river; in the Degrobois deposit; and in the Grondin and Beauceville mines. Ilmenites in the parish of St. Urbain and at Ivry. Iron sands containing from 1.5 to 2 per cent. titanium on either side of the mouth of the Moisie river. P. 369: reduction of ilmenite ores by the Goldschmidt thermit process and by electric smelting.

Extraction of iron free from titanium from titaniferous ferruginous sands. 1913. (Jour. Soc. Chem. Ind., vol. 32, p. 1017, abst. from Ledebeer's French Pat. 456,401.)
By mixing the sands, after preliminary magnetic concentration, with carbon and reducing at a temperature insufficient to melt the reduced iron.

KELLOGG, L. O.
Experiment in smelting titaniferous magnetite. 1913. (Eng. and Min. Jour., vol. 96, p. 604.)
Note on proposed treatment of Adirondack high-titanium ores by mixing them with ordinary magnetite.

SINGEWALD, J. T.
Titaniferous iron ores in the United States, their composition and economic value, 1913, Washington, Bur. of Mines, Bull. 64, pp. 141. (See editorials in Eng. and Min. Jour., vol. 96, pp. 654, 678, 705.
(Pp. 10-15: smelting in the blast furnace; pp. 15-17 smelting in the electric furnace; pp. 17-24: magnetic concentration of titaniferous magnetites.

VOSMAER, A.
Titanium iron sand. 1913. (Chem. Abst., vol. 7, p. 57, abst. from Chem. Weekblad, vol. 9, pp. 726-733.)
States that this ore is not well adapted to the blast furnace process, because of the high temperature necessary to fuse the titaniferous slag. Use of electric furnace recommended. Carbon is used for reduction of ores, and steel of superior quality may be obtained.

1914—BACHMAN, F. E.
The use of titaniferous ore in the blast furnace. 1914. (Year Book, Am. Iron and Steel Inst., pp. 371-419; abst., Chem. Abst., vol. 10, p. 1152.)
Detailed account of experiments made in the blast furnace at Port Henry, N.Y. States that titaniferous concentrates are reduced with less expenditure of heat and consequently of fuel than non-titaniferous magnetites. Details on amount of slag produced, on operation of the furnace, etc. Illustration shows details of blast furnace used.

BEYSCHLAG, F., VOGT, J., and KRUSCH, P.
Deposits of useful minerals and rocks, 1914, London, Macmillan, vol. 1, pp. 514.
P. 256: occurrence of ilmenite ores with 35 to 40 per cent. of TiO_2 in the large labradorite districts of Canada.

CONE, E. F.
Titanium ores in the blast furnace. 1914. (Iron Age, vol. 94, pp. 936-939.)
Illustrated description of smelting process. Composition of concentrates of titaniferous iron ores, furnace data, etc. Illustration shows cross-section of the hearth of the furnace after the run on titaniferous iron ores.

Reduction of titaniferous ores. 1914. (Iron Tr. Rev., vol. 55, p. 418.)
Results obtained with Tahawus magnetite iron ores containing titanium.

ROSSI, A. J.
Metallurgical method. U.S. Pat. 1,104, 317. 1914. (Off. Gaz., vol. 204, pp. 813-814; abst., Jour. Soc. Chem. Ind., vol. 33, p. 870.)
By melting together at below 1700°C., a mixture of carbon, titaniferous iron ore, and oxide of manganese.

SIMMERSBACH, O.
Verhuttung titanhaltiger Eisenerze im Hochofen. 1914. (Stahl und Eisen, vol. 34, pp. 672-674; abst., Iron Age, vol. 93, p. 1525.)
Smelting of titaniferous ores with 11.82 per cent. titanium in blast furnaces and results obtained. Electric smelting was successful as long as titanic acid in the slag was below 2 per cent.

Slags from titaniferous ores. 1914. (Iron Tr. Rev., vol. 55, pp. 1040-1042.)
Laboratory tests on ores high in titanium, preliminary to blast furnace tests. Illustration shows vertical section of Port Henry furnace.

STARK, C. J.
Reduction of titaniferous ores. 1914. (Iron Tr. Rev., vol. 55, pp. 721-726, 742; abst., Jour. Iron and Steel Inst., vol. 91, 1915, p. 549.)
Details of experiments at Port Henry with magnetic ores high in titanium. The blast furnace and its condition at the end of run is described in detail and analyses of the iron and slag obtained are given.

Titaniferous ores in the blast furnace. 1914. (Iron Age, vol. 94, pp. 1470-1473.)
Conclusions from the Port Henry experiments; titaniferous concentrates are reduced with favorable fuel consumption. Attention is given to earlier experiments with titanium ores and their behaviour in the blast furnace.

Titanium. 1914. (Min. and Sci. Press, vol. 109, p. 983.)
Briefly describes experiments to determine the feasibility of smelting the ore from Sanford Hill. Experiments showed that the slag was unusually fluid and the coke consumption normal.

1915—BERGGREN, P. H.
Titanium and titaniferous ores. 1914-15. (Sibley Jour. Eng., vol. 29, pp. 227-230.)
States that magnetic concentration after crushing has but little success. Deals briefly with electric smelting of titaniferous ores.

COMSTOCK, G. F.
Titanium and its effects on steel. 1915. (Jour. Soc. Chem. Ind., vol. 34, pp. 55-57.)
Deals briefly with the reduction of natural titanium oxides by means of the electric arc, or by an alumino-thermic reaction.

DULIEUX, E.
Les minerais de fer, 1915, Quebec, Service des Mines, pp. 243.
Pp. 51-136; location of titaniferous iron ores; District of Saguenay, St. Laurent, Shawinigan, St. Urbain, etc. Pp. 176-183; direct smelting of titaniferous iron ores in the blast furnace and in the electric furnace. Pp. 183-199: review of various smelting experiments. Pp. 200-205: comparison of the blast furnace with the electric furnace. Pp. 211-214: reduction of titaniferous iron.

FARUP, P.
Process of producing titanium-oxygen compounds from ilmenite or titaniferous iron ores and other materials. U.S. Pat. 1,156,220. 1915. (Off. Gaz., vol. 219, p. 335.)
By treating the material with sulphuric acid, heating to a temperature at which the titanium sulphates are decomposed and leaching the resulting mass.

JOHNSON, J. E.
Chemical principles of the blast furnace. 1915. (Met. and Chem. Eng., vol. 13, pp. 634-638.)
Note on some difficulties in fusing ores containing titanic acid. Sees the reason in the affinity of titanic acid for nitrogen.

KENNEY, R. M.
Electric smelting of ferro-alloys. 1915. (Iron Tr. Rev., vol. 56, pp. 765-767.)
P. 767: reviews briefly methods of producing ferro-titanium by means of blast furnace and electric furnace, and Goldschmidt's thermit process. Describes the manufacture of ferro-titanium by reduction with carbon by the electric arc. By refining the product obtained an alloy is made having 10 to 15 per cent. titanium.

STOUGHTON, BRADLEY.
Smelting of titaniferous iron ores, 1915. (Trans. Can. Min. Inst., vol. 18, pp. 140-147, disc. pp. 148-152.)
Previous experiences in smelting, recent smelting experiments, bibliography.

1916—BARTON, L. E.
Method of obtaining titanic oxide. U.S. Pats. 1,206,796, 1,206,797, and 1,206,798. 1916. (Off. Gaz., vol. 233, pp. 5-6.)
By heating titaniferous-ferruginous materials in presence of sulphide of an alkali metal at temperature below that of fusion of the charge, etc.

CLARKE, F. W.
Data of geochemistry, 1916, U.S. Geol. Surv., Bull. 616, pp. 821.
P. 348: occurrence of ilmenite in Canada at St. Urbain.

Direct production of refined iron and refined steel from titaniferous iron ores. 1916. (Jour. Soc. Chem. Ind., vol. 35, pp. 52-53, abst. from Lake's Eng. Pat. 5,618. 1915.)
By melting titaniferous iron oxides, obtained from titaniferous iron sand by concentration in an electric furnace of the resistance type with carbon monoxide or water gas.

Extraction of iron free from titanium, from titaniferous ferruginous sands. 1916. (Jour. Soc. Chem. Ind., vol. 35, p. 605, abst. from Ledeboer's German Pat. 290,631. 1913.)
By mixing with carbon and heating in a reducing atmosphere in a reverberatory furnace.

High titanium products from ilmenite. 1916. (Eng. and Min. Jour., vol. 102, p. 832.)
Difficulty in bringing mineralized TiO_2 into solution with acid and decomposition of basic sulphate of titanium with water in the heat.

ROSSI, A. J.
Method for obtaining titanic oxide. U.S. Pat. 1,184,131. 1916. (Off. Gaz., vol. 226, p. 1193.)
From ore containing it, intermixed with ilmenite by melting it with bisulphate of soda, the melt obtained being boiled with water with addition of acid.

STANSFIELD, ALFRED.
Electric smelting as a means of utilizing the iron ore of the St. Charles deposit. 1916. (Can. Geol. Surv., Memoir 92, pp. 52-73; abst., Eng. and Min. Jour., vol. 103, p. 1020.)
Location and properties of the ore. Review of smelting processes of titaniferous iron ores. Electric smelting of St. Charles ore and concentrates. Reduction of titaniferous iron ores. Blast furnace smelting of the St. Charles ore.

WITHERBEE, F.
Iron ores of Adirondacks. 1916. (Iron Tr. Rev., vol. 59, pp. 891-894.)
Deals briefly with the concentration of titaniferous magnetite ores.

1917—ANDERSON, R. J.
Metallurgy of titanium. 1917. (Jour. Franklin Inst., vol. 184, pp. 469-508, 636-650, 885-900.)
Detailed study of the occurrence (Canada), treatment, smelting, reduction, etc., and uses of titanium and its compounds. Paper is accompanied by illustrations and bibliography.

ANDERSON, R. J.
Metallurgy of titanium ferro-alloys. 1917. (Iron Tr. Rev., vol. 61, pp. 335-338.)
Mentions occurrence of rutile in Canada; briefly describes reduction of titaniferous iron ores.

Canadian Mining Journal, 1916-1917.
P. 176: note on occurrence of titaniferous iron ores at Baie St. Paul, Que.

Distribution and uses of titanium ores. 1917. (Bull. Imp. Inst., London, vol. 15, pp. 82-98; abst., Jour. Soc. Chem. Ind., vol. 36, p. 1012.)
Pp. 83-84: occurrence of titaniferous iron in Canada. Pp. 86-87: reduction of titaniferous iron ores, concentration of low percentage titaniferous ores. Pp. 92-95: smelting of titaniferous ores in the blast furnace and in the electric furnace.

Process of producing titanium-oxygen compounds. 1917. (Jour. Soc. Chem. Ind., vol. 36, p. 1272, abst. of Norske Aktieselskab's Eng. Pat. 102,059. 1916.)
By treating titaniferous iron ores with a decomposing agent in a quantity less than theoretically required.

Process of reducing titaniferous-iron ores. 1917. (Jour. Soc. Chem. Ind., vol. 36, p. 1134, abst. from Loke's Eng. Pat. 109,328, 1916.)
By mixing them with pyrites and by heating the mixture in an electric furnace.

Report of the Royal Ontario Nickel Commission, with appendix, 1917, Toronto, Wilgress, pp. 584.
P. 29: note on occurrence of titaniferous iron near Whitefish lake.

STANSFIELD, ALFRED.
Canadian metallurgy during 1916. 1917. (Can. Min. Inst., Bull. 57, p. 12.)
Electric smelting experiments of titaniferous ores at McGill University.

STANSFIELD, ALFRED, and WISSLER, W. A.
Smelting of titaniferous ores of iron. 1917. (Chem. Abst., vol. 11, p. 932, abst. from Trans. Roy. Soc. Can., 1916, vol. 10, No. 3, pp. 33-42.)
Gives composition of the titaniferous magnetic ores in Canada. Possibility of smelting these with SiO_2 as well as $CaCO_3$ as a flux. Use of concentration by magnetic separation. Chart showing amounts of fluxes required.

WHITTON, C. F.
Present position and future of iron and steel industries in Canada. 1917. (Trans. Can. Min. Inst., vol. 20, pp. 331-372, disc. pp. 373-388.)
P. 379: note on the abundant occurrence of titanium-bearing iron ores in Quebec.

1918—DAUNCEY, W. G.
Metallurgical notes. 1918. (Can. Min. Inst., Bull. 79, p. 938.)
Titanium steel; use of ferro-titanium alloy.

Electric furnace reduces titaniferous ores. 1918. (Iron and Steel of Canada, vol. 1, p. 199.)
Note on smelting the ore in a three-phase electric furnace equipped with 3 electrodes and having a capacity of 2 tons per 24 hours. Process has been patented by Rothert, Seattle.

ESCARD, JEAN.
Electric furnace reduction of certain metals susceptible of industrial utilization. 1918. (Rev. Gen. de l'Elec., vol. 4, No. 11, Sept. 14, pp. 375-386.)
Notes on reduction of titanium.

GOODWIN, W. L.
Titaniferous ores of Canada. 1918. (Can. Chem. Jour., vol. 2, p. 210; abst., Chem. Abst., vol. 21, p. 1962.)
Occurrence and uses of titanium-iron ores and their utilization.

LAKE, W. A.
Titaniferous iron ore reducing. New Zealand Pat. 39,677. 1918. (Pat. Off. Jour., vol. 7, p. 194.)
In an electric furnace with pyrites as a reducing agent.

Process for treatment of ilmenites or titanic iron ores. 1918. (Jour. Soc. Chem. Ind., vol. 37, p. 2124, abst. from Raffin's Eng. Pat. 111,668, 1917.)
Concentration is effected by adding an agglutinant to a mixture of the ore and carbon, heating and subjecting the product to action of dilute H_2SO_4 or HCl to dissolve iron.

RAFFIN, M. R.
Concentration of titanium ores. U.S. Pat. 1,256,368. 1918. (Off. Gaz., vol. 247, p. 408; abst., Jour. Soc. Chem. Ind., vol. 37, p. 212A; Raffin's Eng. Pat. 111,668, 1917.)
Concentration effected by adding an agglutinant to a mixture of the ore and carbon, by heating and subjecting the product to action of dilute H_2SO_4 or HCl to dissolve the iron, by washing and drying the titaniferous residue obtained.

ROSSI, A. J.
Development of metallurgy of titanium. 1918. (Met. and Chem. Eng., vol. 19, pp. 117-120; see also Jour. Soc. Chem. Ind., vol. 37, pp. 731-735T.)
Brief description of experiments in smelting titaniferous ores containing 15 to 18 per cent. TiO_2 and 55 to 56 per cent. metallic iron. Reduction of titaniferous iron with carbon in an electric arc furnace. Points out that presence of about 1.5 per cent. TiO_2 in the ores and of 2 to 2.5 per cent. in the slags had no effect on working of furnaces.

Titanium and rutile. 1918. (Engineering, vol. 106, p. 50; abst., Jour. Iron and Steel Inst., vol. 98, p. 434.)
Occurrence of large deposits of ilmenite at St. Urbain, near Baie St. Paul. Ilmenite and rutile containing 45 to 50 per cent. of TiO_2 are found in the ore bed.

WARREN, C. H.
On microstructure of certain titanic iron ores. 1918. (Econ. Geol., vol. 13, pp. 419-447.)
Pp. 433-434: contains data on titanic iron ores of Canada with special reference to ilmenite at St. Urbain, Que.

1919—AUBEL, V. W.
Titaniferous iron sands of New Zealand. 1919. (A.I.M.E., Bull. 153, pp. 2081-2095.)
Difficulties in production of pig iron in the blast furnace from titaniferous iron sand. Experiments with the magnetic separator, treatment in blast roasting furnace and smelting in the furnace. Detailed illustrated description of the blast furnace plant and results obtained.

GOODWIN, W. L.
Titaniferous iron ores in Canada. 1919. (Trans. Can. Min. Inst., vol. 22, pp. 86-94; criticism on article, Can. Min. Inst. Bull., 1919, pp. 1052-1057.)
Mentions chief occurrences of titaniferous iron ore in Canada and describes the metallurgical problems met with in their utilization.

GIBSON, C. B.
Ferro-alloys in electric furnaces. 1919. (Elec. Jour., vol. 16, p. 366.)
Discusses the use of ferro-titanium.

Making steel in Canada. 1919. (Can. Mach., vol. 21, No. 23, pp. 567-572.)
Contains references to titaniferous iron ore deposits in Eastern Canada.

Waddell, John.
Estimation of titanium in iron ore. (Analyst, vol. 44, No. 522, 1919, pp. 307-309.)
Rapid method for the estimation of titanium in titaniferous iron ores, in use at Queen's University, Kingston.

1920—Bertrand, M. F.
Note on the industrial uses of titanium. 1920. (Rev. Univ. des Mines, vol. 5, No. 2, pp. 139-155.)
Includes comparative analyses of ferro-titanium and ferrocarbo-titanium.

Escard, Jean.
Electrometallurgical production of ferro-titanium. 1920. (L'Ind. Chim., vol. 7, pp. 188-190.)
Reviews the Rossi and Borchers processes and refers to the experiments of Guillet, Braune, and Lamort.

Halen, S.
The use of titanium and its compounds. 1920. (Edel Erden und Erz., vol. 1, No. 24, pp. 237-242.)
Reviews foreign and domestic patented processes.

Heskett, J. A.
Utilization of titaniferous iron ore in New Zealand. (Jour. Iron and Steel Inst., vol. 101, pp. 201-215.)
Describes tests made to utilize titaniferous iron sands as ore for blast furnace.

Investigation of iron ore deposits in Northern Ontario, 1920, Can. Dept. of Mines, Summary Report, No. 542.
Describes the deposits, mining operations, and output of titaniferous iron ore.

The iron ore occurrence in Alberta. 1920. (Iron and Steel Can., 1920, vol. 3, pp. 185-190.)
Summarizes the existing information on the known iron ore deposits of Alberta including some occurrences of titaniferous magnetite.

Lamort, Z.
Iron titanium alloys. (Metallkunde II, 1920, pp. 35-39.)
Discusses the manner in which the titanium is mixed with the iron in the alloy.

1921—Action of titanium in blast furnace slags. (Chem. and Met. Eng., vol. 25, Oct. 26, 1921, pp. 801-802.)
Short discussion of the subject by the editor.

Avis, J. L.
Making pig iron and steel from Pacific Coast black sands. (Iron Tr. Rev., vol. 69, No. 13, 1921, pp. 810-812.)
Details of experimental furnace built by William Tyrrell in 1920 which has capacity of 10 tons, an inside hearth diameter of 30 inches and a height of 35 feet. Describes process of smelting titaniferous iron-bearing sands, by briquetting or with aid of natural binder and melting briquettes in ordinary blast funace.

Osann, B.
Das Vorkommen und Verhalten von Titan in Roheisenmischer. 1921. (Stahl und Eisen, vol. 41, pp. 1487-1489.)
The paper discusses occurrence and behaviour of titanium in the pig iron mixer.

1922—Determination of titanium in cast iron. (Foundry, vol. 50, pp. 456-498a: June 1, p. 456a; June 15, p. 498a.)
Describes a colorimetric method for determination of titanium.

4. Treatment and Utilization of Siderite Ores

1911—Birkenbine, J.
Concentration of iron ore. 1911. (Iron Tr. Rev., vol. 48, pp. 265-272.)
Describes roasting, washing, and briquetting of iron ores.

Campion, A.
Calcining fine iron ore. 1911. (Eng. Rev., vol. 25, p. 120.)
Describes calcining and nodulizing of fine iron ores at the Clyde Iron Works, Scotland.

Meuskens, Clemens.
Abbau im Bergrevier Siegen, Kattowitz, Bohemia. 1911. (Sammlung Berg- u. Hüttenmännischer Abhandlundgen, vol. 78.)
Describes the mining and handling of siderite ore in the Siegen mining district, Germany.

1912—Harnickell, W.
Preparation of spathic ore. 1912. (Stahl und Eisen, vol. 32, pp. 1949-1955.)
Deals with the preparation of spathic ore for blast furnace practice in Siegerland, Germany. The processes employed are both mechanical and electrical, the latter being applicable only to the calcined ore.
Adverse criticism of this article. (Stahl und Eisen, vol. 33, 1913, pp. 1735-1740.)

Sexton, A. H.
An outline of the metallurgy of iron and steel, 2nd ed., 1912, pp. 41-53.
Contains information on preparation of siderite ores for the smelter.

1913—Calcination of blackband ironstone. (Iron and Coal Tr. Rev., vol. 36, 1913, pp. 443-445.)
Gives particulars on the calcination of blackband ironstone at the Parkhouse mine, Newcastle, Staffordshire.

1914—Eckel, E. C.
Iron ores, 1914, London and New York, McGraw-Hill Company.
Gives general information on main occurrences, iron contents, concentration, calcining, and mining costs of iron carbonate ores.

Nagel, Oscar.
Iron ore output at the Styrian Erzberg. 1914. (Iron Age, Aug. 27.)
Describes how large amounts of carbonate iron ore (10,000 tons daily) are mined and handled.

1915—John, W.
Roasting kilns for spathic ore. 1915. (Glückauf, vol. 51, pp. 57-59.)
Account of shaft kilns in use in the Bilbao (Spain) mining district for iron carbonate ore, with capacity of 56 to 78 tons per day.

1918—Barnes, W.
Mining iron ore in the Midlands. 1918. Min. Mag., vol. 18, p. 120.)
The author gives particulars of the method of opening and mining, and of the machines employed for the Jurassic (carbonate) iron ores in the Midland Counties in England.

Hatch, F. H.
The Jurassic ironstones of the United Kingdom. (Jour. Iron and Steel Inst., vol. 97, 1918, pp. 71-126.)
The paper contains detailed description of the various ironstones, the methods of working them, and disposal of output.

1919—Calcining kilns. 1919. (Iron and Coal Tr. Rev., vol. 98, pp. 435-436.)
Description of 16 kilns of the Gjers type at the Ebbw Vale Iron and Coal Company.

5. Electrolytic Iron

1846—BOETTGER, R.
(Ann. Physik u. Chem., vol. 67, p. 117.)
An account of first production of electrolytic iron.

BOETTGER, R.
(Vers. für Chem. und Phys. Vorles, 1846, Frankfurt, p. 7.)

1861—KRAEMER.
(Chem. Centralblatt, 1861, p. 273.)

1864—PERCY, JOHN.
Metallurgy, iron and steel, London, John Murray, 1864, p. 2.
Describes pure iron precipitated from chloride solution by Bradbury.

1866—MOORE.
(Chem. News, vol. 53, p. 209.)

1867—MEIDINGER.
(Beil. zu. Nr. 12 d. bad. Gewerbetztg, vol. 31, p. 12.)

1868—KLEIN, E.
(Soc. d'Encouragement, 1868, p. 286.)

STAMMER.
(Dingler's Poly. Jour., vol. 190, pp. 116, 258.)

VARRENTRAPP, F.
Galvanic precipitation of iron in coherent form. 1868. (Dingler's Poly. Jour., vol. 187, p. 152.)

1869—JACOBI, M. H. VON.
Note sur la production des dépôts de fer. 1869. (Bull. Acad. Imp. Sci. St.-Pétersbourg, vol. 13, p. 40.)

JACOBI, M. H. VON.
On the electro-deposition of iron. (Brit. Assoc. Rept., 1869, p. 67.)

LENZ, R.
(Jour. Prakt. Chemie, vol. 108, p. 438.)

1875—CAILLETTE, L.
(Compt. Rend., vol. 80, p. 309.)

1878—PARODI and MASSAZINI.
(Gazz. Chim. Ital., vol. 8, p. 169.)

1880—LUCKOW.
(Zeit. Anal. Chemie, vol. 19, p. 18.)

1887—ROBERTS AUSTEN, W.
The electro-deposition of iron. 1887. (Jour. Iron and Steel Inst., 1887, Pt. I, p. 71.)

WATT, A.
Electrolysis of iron salts. 1887. (Electrician, Nov. 11 and 25, Dec. 16 and 30, 1887.)

1889—BRANDT.
(Zeit. Anal. Chemie, vol. 28, p. 581.)

SMITH.
(Am. Chem. Jour., vol. 10, p. 330.)

1891—THIELE.
(Liebig's Ann., vol. 58, p. 265.)

1893—VORTMANN.
(Monatsh. Chemie, vol. 14, p. 536.)

1894—ARNOLDS and HADFIELDS.
(Stahl und Eisen, 1894, p. 526.)

1895—Hicks, W. M., and O'Shea, L. T.
Some points on preparation of pure iron. 1895. (Electrician, vol. 35, p. 843; Zeit. Elektrochem., vol. 2, p. 406; Brit. Assoc. Rept., 1895, p. 634.)

Hiorns.
(Electrician, 1895, pp. 843, 910.)
(Zeit. Elektrochem., vol. 2, 1896, p. 648.)

1896—Gillivray.
(Industries of Iron, vol. 21, p. 426.)

1897—Foerster, F.
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